ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFREDA WORTH.

OFFICES FOR ADVERTISEMENTS AND PUBLICATION, 35 & 36, BEDFORD STREET, STRAND, LONDON, W.C.

VOL. CI.—No. 2628.] *LONDON: FRIDAY, MAY 12, 1916.* [*Registered at the General Post Office as a Newspaper.*] [PRICE...6d. BY INLAND POST..8d.

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10th May, 1916. E 222

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Messrs. Horne & Co. will SELL by AUCTION on FRIDAY, 2nd JUNE, at Twelve Noon precisely, on the Premises, Cranes Yard, Albion Street, Caledonian Road, a large quantity of NEW AND SECONDHAND MACHINERY AND PLANT by well-known makers, including two Circular Saw Benches to take 36 in., Friction Feed Cross Cut Saw Bench to take 24 in., Circular Saws, 9 in. Four Cutter Planing and Moulding Machine, Double Vertical Spindle Machine, two Single Ditto, one with Canting Table, two Panel Planing and Thicknessing Machines 24 in. by 6 in. and 18 in. by 6 in., 6½ H.P. Gas and 15 H.P. Oil Engines by Crossley Bros., four Motors, Dynamo, Bootmaking Machinery, 30 in. Auto Knife Grinder, Power Mortising, Wood Boring, Pillar, and Wood Planing Machines, five Power and Foot Lathes, Jeweller's Turning Lathe, Impact Testing Machine, Devil Tearing Machine, two Albion Presses, four Zinc Lined Seed Separators, Seed Dusting, Coffee Roasting and various other Machines, Concrete Mixer, Grinding Mill, 5 H.P. Portable Engine, Leather Belts, 15 tons New Bolts, Nuts, Rod and Bar Iron, eight Single and Double Purchase Crabs 1½ to 10 tons, 13 Anvils, Vices, six Bellows, Single and Double Fans, Pulley Wheels 10 in. to 72 in., Cog, Bevel, Mortise and Jenny Wheels, 40 Plummer Blocks and Brasses, 12 Hand, Steam and Pulsometer Pumps, five Weatons Endless Tackle 3 to 6 ton, Sheave Blocks, Contractors' Rails, Trolleys, Skips, Axles and Wheels, two Iron Framed Carriages, Friction Hoist, 20 Ships' and 26 other Tanks, and a large assortment of Tools and Miscellaneous Items.
May be viewed two days previous. Catalogues had of the Auctioneers, 35, Old Queen Street, Westminster, and 85, Gresham Street, E.C. E 208

PRELIMINARY ANNOUNCEMENT.
Re CONSOLIDATED DIESEL ENGINE MANUFACTURERS, LIMITED.
(In Liquidation.)
DIESEL ENGINE COMPANY, LIMITED.
(In Liquidation.)
TO ENGINEERS, SHIPBUILDERS, POWER AND LIGHTING COMPANIES, FACTORY AND MILL OWNERS, AND OTHERS.

Wheatley Kirk, Price & Co., have been instructed by the Liquidator, Sir WM. B. PEAT, to SELL by PUBLIC AUCTION, at an early date, upon the Works at Ipswich, the whole of the Stock of
NEW LAND AND MARINE TYPE DIESEL ENGINES, SPARE PARTS AND STORES, including:—
One 200 h.p. three-cylinders, land-type.
Four 100 h.p. four-cylinders, ,,
One 100 h.p. two-cylinders, ,,
One 50 h.p. two-cylinders, ,,
Five 25 h.p. single-cylinder, ,,
Spare parts for each type.
Patterns, Drawings, and Jigs, for ditto.
One D4 Marine-type (port).
Two D5 ,, (starboard).
Three "Reavell" duplex Air-Compressors.
One "Gwynnes" 3000 gals. electric Tandem Pump.
One "Albany" 3000 gals. ,, ,,
One "Reavell" 4 ins. Centrifugal Pump and duplex Air-Compressor.
One "Mather & Platt" tandem Turbine Pump, 50 gals.
General Stores.
Catalogues are in course of preparation, giving photos, tests and weights of the engines, for which apply to the Liquidator, SIR WM. B. PEAT, of Messrs. W. B. Peat & Co., Chartered Accountants, 11, Ironmonger Lane, London, E.C.; or the Solicitors, Messrs. Gowrie & Son, 65, Wool Exchange, London, E.C.; and Messrs. MAYO, ELDER & Co., 10, Drapers Gardens, London, E.C.; or to
THE AUCTIONEERS,
46, Watling Street, London, E.C.,
also at Manchester and Newcastle-on-Tyne. E 225

THE IRON AND STEEL INSTITUTE.

IN our last issue we reported the preliminary proceedings of the forty-seventh annual general meeting of the Iron and Steel Institute. After the presidential address, the first paper taken on Thursday, the 4th inst., was one by Sir Robert Hadfield, D.Met., F.R.S., and Mr. J. N. Friend, D.Sc., entitled

THE INFLUENCE OF CARBON AND MANGANESE UPON THE CORROSION OF IRON AND STEEL.

It was read in abstract by Mr. J. N. Friend. We reproduce it in full on page 445 of the present issue.

THE THEORY OF THE CORROSION OF STEEL.

A paper bearing the above title, by Mr. Leslie Aitchison, M.Met., B.Sc., was taken in conjunction with the first. We reproduce it also in the present issue on page 461. It was read in abstract by the author, who in his opening statement said it was a very theoretical contribution, which he hoped would be fully discussed and lead to further knowledge on the subject of corrosion.

The work he had carried out pointed to the corrosion of steel taking place purely by the action of the ferrite or the solid solution. The action upon pure ferrite might be due entirely to the potential difference set up in consequence of the different solution pressures of the grains of the metal and the inter-granular cement, it being probable that this latter was possessed of a greater electromotive force. The percentage of the third element added to iron and carbon in steels had to be sufficiently great to produce a fairly high percentage in the solid solution, if there was to be any effect from the use of this element. The electromotive force of the solid solution with respect to the corrosive liquid was the deciding factor in the corrosion of a steel. The pearlite did not corrode as a whole, but as a mixture of ferrite and cementite, the disappearance of the latter being due to mechanical, and not to chemical action. Carbides were not decomposed by ordinary corrosive agents; they acted merely as cathodes to the anode of the ferrite or solid solution.

The discussion was opened by Sir Robert Hadfield, who thanked his colleague, Mr. Friend, who had found time, notwithstanding his war work, to carry out the experiments referred to. Mr. Aitchison had stated that few steels containing a third element had any advantage to offer over those containing only iron and carbon, with the exception of those containing a high percentage of chromium, and in regard to this, added Sir Robert, we never seemed to be getting nearer to the reduction of waste by corrosion. He (the speaker) had recently had an experience of the effect of chromium in reducing corrosion. About twenty years ago he put in his private museum some test-pieces which had been experimented upon; they contained about 0.6 per cent. of carbon and 10 to 12 per cent. of chromium. He recently took them out of the museum and found them practically in the same condition as twenty years ago; they were not oxidised; it is true that they had not been in the open air, but they had been lying by for a long time. These specimens were not brittle, and the metal would be of benefit in ship construction; the percentage of chromium required, however, seemed high. In these chromium steels the percentage of carbon had to be maintained low. By cutting down the carbon content and adding to the chromium an alloy was obtained which was not corrosive. His paper (Sir Robert's and Mr. Friend's) showed the loss in the acid solution, and Mr. Aitchison's figures confirmed that loss. Mr. Aitchison's paper was a most valuable one and was most heartily welcome as an extension of researches on the problem of corrosion; losses through this cause were enormous and required to be greatly reduced. He (the speaker) had recently had a conversation on the subject with Sir John Wolfe Barry, in regard particularly to the corrosion going on in civil engineering works to an enormous extent, and lock-gates were instanced, the repairs to which were most difficult to carry out.

Dr. Stead, who followed, pointed out the extreme variety in the results obtained. He (the speaker) had exposed wires to all possible conditions. He had aken wire specimens, both hard-drawn and normalised, in order to ascertain whether the metal hardened by cold work corroded more rapidly than the normalised. He had placed several series of specimens on the roof of his laboratory, where they were exposed to the smoke and fumes of his laboratory and also to those of Middlesbrough. Other series he had placed inside his laboratory; others, again, in a tower condenser; and in the Tees, between the high and low-water marks. A fifth series he placed on the top of his residence at Redcar, where they were exposed to the sea atmosphere; and a sixth series he sent to the country in Yorkshire, where they were far from all fumes of any sort. Every six months he had had a series taken up for observation purposes. One set only was high in manganese, and he found that it did not corrode differently from the others. The sulphur content was low in each case. The relative loss he indicated as follows. If he gave to the series exposed in the country the figure 100, then the series coming from his residence at Redcar showed 200, those in the River Tees 250, those in the tower condenser 220, those inside his laboratory 125, and those on the roof of his laboratory 500. There were very similar corrosion effects upon wrought iron and soft steel. The satisfactory figure for the series exposed inside his laboratory he accounted for by the dryness of his laboratory; an outside coating was formed round the wire which acted as a protection, and there was no water to put the corrosive agent in contact with the wire. As would be seen, therefore, the result was very similar in his laboratory and in the country air of Yorkshire.

Acid tests conducted in a laboratory formed no criterion. It was difficult to explain the zigzag of the curves in Sir Robert Hadfield and Mr. Friend's paper. But it was interesting to note that the addition of 0.7 per cent. of manganese resulted in a slightly increased corrosion in water and in wet and dry tests, and in an increased corrosion in dilute sulphuric acid. Since 0.6 to 0.7 per cent. was the usual percentage of manganese in the steel of wire ropes for mines, it was incumbent upon the wire-rope makers to take care of the percentage of manganese. It had been found that by the addition of 0.2 per cent. of copper to the steel for wire ropes the resistance to acid corrosion of the ropes was greatly increased. The ropes which stood the longest were those which were made with steel containing a slight copper addition. In natural conditions the copper addition did not make much difference; there was, however, a great difference in the case of acids, when the wire without copper corroded as to 2 to 1 for the wire containing copper.

In regard to the second paper, Dr. Stead asked whether Mr. Aitchison was aware that a pure crystal corroded as rapidly as aggregate crystals. Here Dr. Stead exhibited a small model and a photograph to show that a round pin-hole in a flat piece of steel would extend and become square by subjecting the piece to corrosion; in the case of a sphere the corrosion would extend to form a cross. He further exhibited a specimen in which, he said, the intercrystalline cement which he was trying to get was found to be electro-positive and not electro-negative to the crystal; he pointed out also the different behaviour which would take place after breaking a piece along the junction of the crystals instead of cutting it and etching the surface. He added that he felt sure the excellent work done by the author would lead others to carry out researches in the same field, the result being that more light would be thrown upon the subject and more truth would be arrived at.

Dr. W. Rosenhain said he had not had time to give to the papers the careful study they deserved. There was no doubt at all that the question of the influence of manganese on the corrosion of steels of various carbon contents had been a much-debated question, and it was extremely interesting and useful to have the systematic results which had been given in the papers. But looking at the results from the point of view of a set of scientific experiments, he was a little inclined to doubt whether they bore quite the detailed interpretations the authors put upon them. It was not sufficient to talk about maxima and minima in a curve when there were isolated experimental points only. It was true that the curves, taken all together, showed a certain correspondence, but before one could place very much reliance on them it would be necessary to have more results. It would be necessary also to show that those apparent maxima and minima agreed consistently in half a dozen series. The subject of Mr. Aitchison's theory he had discussed to some extent elsewhere. He was naturally interested in the subject of the intercrystalline cement, and perhaps might be allowed to refer to what Dr. Stead had just said. First of all, that little experiment of etching a needle-prick in the centre of an isolated crystal was a totally unfair experiment scientifically, because the crystal had been strained and its truly crystalline character destroyed at the point at which it was going to be etched. It had produced a considerable amount of that very amorphous material just around the pin-prick, and that amorphous material had distributed itself along the crystalline planes of the crystal and no doubt served to break the corrosion along those lines. Dr. Stead had spoken of trying to get the cement. If he had tried to get it by breaking crystals apart, he was trying to do something which was quite impossible. In order to get crystals to break apart at all, they had to be in an abnormal condition altogether, and he would be glad to know how Dr. Stead did it. Having done it, the whole material was in a strained condition and the whole experiment was completely upset. The real way of testing whether the amorphous material was anodic or cathodic was by testing strained cold-worked steel or iron. In that way one thing was in the presence of the other, and if there was greater or less corrosion there was some ground for thinking that the cement or amorphous material might be more or less corrodible than the unstrained. The corrosion figures which followed along the surface of strain certainly indicated there was a very strong difference, but what that difference was he thought had still to be settled.

Dr. W. H. Hatfield, who followed, stated that the question of corrosion had always been one in which he took a lively interest. In the first paper reference had been made to the experiments carried out by Heyn and Bauer with cast iron, the percentages of manganese were given, and the claim in regard to relative corrosion was made for the manganese as such; he thought the condition of the carbon should have been given also, for if the carbon were high, corrosion took place at a less rate. The diagram in the first paper, giving the curves of the authors, with those of Chappell and Aitchison for the corrosion of steels of low manganese content in sea-water, showed great discrepancy; they were not comparable at all, and he (the speaker) suggested that all three curves were correct, that they should be accepted as such, and that more data should be given by the respective authors to explain the discrepancy. It was interesting that low carbon steel high in manganese corroded rapidly in sea-water. Dr. Hatfield added that researchers should confine themselves to facts, and with respect to one point in Mr. Aitchison's paper, the author had stated that in the case of a nickel alloy the carbide was found to be free from nickel until the steel contained more than 8 per cent. of nickel; he (the speaker) said that even 3 per cent. of nickel had a large influence on the stability of the carbide in steel, rendering the carbide less stable. He welcomed both contributions.

Mr. Saniter found that important points had been thrown out by the authors, showing that manganese steel was not so corrodible at it was thought to be. He added, with particular reference to one of Dr. Stead's statements, that he had experimented with various steel alloys both in his laboratory and by exposing them in the Woodhead Tunnel, Sheffield. In the laboratory, acid steels were attacked more seriously than basic steels, the 3 per cent. nickel steel specimens in the tunnel were attacked less severely than any, and there was no difference between the acid and the basic steels after exposure in the tunnel.

Dr. C. H. Desch said that several speakers had referred to the fact that corrosion experiments usually gave very erratic results, and that always struck one in observing the curves which were obtained by determining the loss of weight by corrosive action. The real reason seemed to be that

there were so many factors involved in the corrosion, and that therefore to make much progress it was necessary to examine those factors as far as possible one by one. That had been done by Mr. Aitchison. Mr. White and himself had carried out work on corrosion, using a method by which the details of the process of corrosion could be followed by the microscope; they did not obtain any very definite results in the case of manganese, owing to the extreme difficulty of obtaining comparable sets of steels. If, however, they had had at their disposal Sir Robert Hadfield's splendid sets, something might have been brought out. In dealing with manganese, they did find that there were certain differences, not merely between the ferrite and carbide, but between the ferrite in the two forms in which it was present in the ordinary steel, namely, the primary crystals of ferrite and the finely-divided ferrite present in the pearlite. In the ordinary cooling of a solution one would expect that those would contain different proportions of manganese, that the first crystals of ferrite would be relatively poorer in manganese than that proportion of the ferrite which entered into the pearlite, the less residual part. One would expect the latter part to be richer in manganese than the first crystals. They had found that there was actually a difference, and, using the methods of applying external electromotive force, they further ascertained that the first crystals of ferrite were always attacked first, and it was not until a certain amount of manganese had been dissolved out that the action extended to the pearlite, although the metal in the pearlite was in a particularly favourable state for corrosion, owing to the presence of the finely divided carbide. One would expect that the inequality in the manganese would be removed by normalising, and that therefore there should be a difference in the behaviour of unannealed and normalised steels. That, he thought, was one explanation of some of the irregularities found in corrosion tests of the kind under discussion. Dr. Stead had referred to the fact that acid corrosion was no guide whatever to the corrodibility of the metal in contact with air, and the reason for that, he thought, was that the corrosion in acid was a very much more simple process than atmospheric corrosion. In the latter there were many factors to investigate, of which very few were known at the present time. Although an immense amount of work had been done on corrosion of steels with very elaborate results, it was still difficult to draw conclusions, because investigators were confounding together a very great number of uninvestigated factors, and therefore laboratory methods by which the factors could be investigated one by one would have to be applied before more definite results could be obtained.

On the motion of the Chairman, who announced that they would reply by correspondence in the Proceedings to the discussion, the authors were awarded a hearty vote of thanks for their contributions.

THE INSTITUTE AND THE STATE.

On the members reassembling on Friday morning, the 5th inst., the Chairman asked Mr. B. Talbot to repeat the statement he had made on the preceding day, with regard to calling a special meeting of the Institute to discuss the duty of the State to the trade, following upon statements which were contained in the presidential address, as the Council wanted to know exactly what was his point.

Mr. Talbot said that on the preceding day he had risen spontaneously to make the remark he did, after listening to the presidential address. He thought the address raised points with which the Institute could very well deal. The position was this: The country stood, as it were, at the division of the ways, and there was no doubt that when the war was over there would be tremendous competition. The Institute was perhaps primarily interested in the scientific side, but the question of economics was also a most important question. He did not see why the Institute should not discuss also the economic side of the problems and thus further the general welfare of trade. The American Institute had, among other things, reduced the number of accidents through the action of one of its departments. In this country there were laws dealing with accidents, but the members of the Institute, by working together, could no doubt improve conditions in this respect also. The Institute could also work for the education of the coming generation. There were a number of capable men, able and ready as competitors, whose resources could be utilised to the full. If progress were to be made, economics should come in. The Institute should approach the State and tell it what was to be done both to preserve and to increase trade.

At this point the Chairman read an abstract of the bye-laws, stating that the objects of the Institute were to afford a means of communication between members of the iron and steel trades upon matters bearing upon their respective manufactures, excluding all questions connected with wages and trade regulations; also to arrange periodical meetings for discussing practical and scientific subjects bearing upon the manufacture of iron and steel.

A discussion followed in which several members took part. It was argued that the foreign members of enemy countries had recently been excluded by virtue of an amendment in the bye-laws, and that it should be possible therefore to act on similar lines in regard to economical questions affecting national and international competition. The decision finally reached was to the effect that the members who were in favour of the views which had been outlined should write jointly to the Council. The Chairman promised that the matter would receive the careful attention of the Council and would come up for discussion at the autumn meeting of the Institute.

RELATIONS BETWEEN THE CUTTING EFFICIENCIES OF TOOL STEELS AND THEIR BRINELL OR SCLEROSCOPE HARDNESS.

The first paper taken at the meeting on Friday, the 5th inst., was one having the above title by Dr. J. O. Arnold, who read it in full. We reproduce it on page 450 of the present issue.

The discussion was opened by Dr. C. A. Edwards, who said that the interesting paper by Dr. Arnold placed him (the speaker) in a rather embarassing position; he had tried to find out who Dr. Arnold had in his mind when he wrote the opening sentences. Perhaps Dr. Arnold referred to a paper which he (the speaker) had recently contributed jointly with Mr. H. Kikkawa. Dr. Arnold had stated that the Brinell hardness of a properly hardened tool was an almost negligible factor of efficiency, the efficiency depending almost entirely on the thermal stability of the simple or compound hardenite in the hardened steel. That, he (the speaker) was quite sure, all would admit; there was no difficulty in that respect; the hardness of carbon steel and that of high-speed steel could not be compared together. Dr. Arnold's further statement to the effect that the Brinell test was worse than valueless for estimating the varying thermal stabilities of the hardenite was another matter; it depended upon how the subject was examined. He (the speaker) could not dismiss the point so summarily. The cutting properties of high-speed steel depended certainly upon the thermal stability of the hardenites, upon their power to resist the softening action of heat. It was simple to test their thermal stability by heating them to a higher temperature and then testing their hardness. He (the speaker) and Mr. Kikkawa did that and referred to it in their last paper. He drew a curve on the blackboard and pointed out that Dr. Arnold's cutting tests agreed with his (the speaker's) views. He also drew a cutting tool and showed how the chip being cut turned round, to wear the top surface of the tool, when the heat generated by friction on the top surface of the tool concentrated in a comparatively small area. He pointed out the influence of the frictional heat. In conclusion, he (the speaker) found nothing in Dr. Arnold's paper to alter the conclusion at which he himself had arrived in his and Mr. Kikkawa's contribution, to the effect that valuable information in regard to the relative merits of high-speed cutting steel could be obtained from careful tempering experiments when made in conjunction with hardness determinations. "When more data had accumulated," the joint authors had added, "this simple method might be found sufficient to replace almost completely the very elaborate and costly standard cutting tests which were now necessary. In any case, it should be extremely useful for ascertaining the best temperature for the second or low heat treatment." There was, he repeated, nothing in Dr. Arnold's paper to cause him (the speaker) to modify that view.

Dr. Stead, who followed, said that when he read Dr. Arnold's paper several points had struck him. One was that he assumed more than he (the speaker) thought he was justified in doing, and a second was that the paper contained much valuable information. It never occurred to him (the speaker) that any person had interpreted the Brinell test as an accurate means for measuring the cutting power of a tool. He added he quite agreed with Dr. Edwards's explanations. Dr. Edwards had referred to the effect of heating to certain temperatures in order to obtain the highest efficiency. Dr. Arnold quoted the cubic inches of metal turned off from the shaft, and that removal of metal gave the very tempering heat that was necessary. "Did he," asked Dr. Stead, "take the hardness numbers after each grinding?"

Professor Turner remarked that if the Brinell test were applied to soft iron, it was found to agree closely with the tensile test; when adding carbon a difference was seen, and in the case of cast iron a very high Brinell figure was obtained, combined with a low tensile stress. A cutting tool was of two parts, one having a high tenacity, the other requiring to be hard and to retain a cutting edge. With high carbon steels the accurate cutting power value could only be given by a cutting test. The author's results at ordinary temperatures were exactly those which he (the speaker) would have contemplated.

After a few remarks by Mr. E. H. Saniter, who found the Brinell test a valuable one for certain classes of steel, and agreed in the main with the former speaker, Sir Robert Hadfield congratulated Dr. Arnold on his contribution, which, although a short one, contained much information. The author's reference to the presence of certain hardenites in the hardened steel, on whose thermal stability the efficiency depended, was an interesting case. Here Sir Robert referred to the prize he had offered for research as to the different forms or combinations of carbon in iron and steel, and stated that beyond Professor Arnold no other scientist had come forward. There was still a good deal to learn in regard to that question. He (the speaker) had spent much time in the study of hardness, and asked the author whether an addition of cobalt would increase or decrease the cutting efficiency of self-hardening steel. One drawback of the author's paper was that in a week or ten days all the information it contained would be in Germany. We should try to keep at home as much information on research work as possible. In concluding, Sir Robert said credit must be given to Dr. Arnold for being the only scientist to study the influence of carbon upon, and the nature of carbides in, steel.

Dr. W. H. Hatfield, who followed, found the paper contained facts in a line with the experience of people who dealt with high-speed steel. He referred to the diagram on the blackboard which had been drawn by Dr. Edwards, and stated that there was an element of danger in attributing too much importance to the Brinell hardness taken at the normal temperature. It was important to ascertain the Brinell hardness figure at the point under the chip on the top of the cutting tool.

Mr. G. H. White stated that he used cutters which he quenched in saltpetre. The quenching in saltpetre gave the steel a whiter grain. He did not temper them. If, however, a deep cut were to be taken, it was better to temper the tool, which then better withstood shocks. He also quenched tools in lead from 1350 degrees, when he obtained a scleroscope hardness of 82, and found no signs of cracking in the tools.

Mr. W. F. Beardshaw would have liked to see in the paper an analysis of the shaft, and an indication of the cutting speeds, and of the feed of the tools.

Professor Arnold, in the course of his reply, stated that he had written his paper with the object of supplying matter of interest to all steel manufacturers, some of whom were suffering from most unreasonable specifications drawn up by people who knew nothing about steel. One horror which these people would demand would perhaps be the Brinell hardness test to ascertain the efficiency of a tool steel on the lathe. He had found that in some

cases the best efficiency was attained after the fourth grinding. He had written his paper on the lines suggested in a remark made by Sir Robert Hadfield, and had not given everything. Since there was a great difference in the tools made from the same bar, he had determined to produce a standard bar. He cast an 18-in. open-hearth acid ingot, which he hammered down to a 13-in. round bar, which he left to cool on end. The manganese was 0.9 per cent., and the carbon also 0.9 per cent. The texture was good and the metal fairly hard. The bar was then turned down to 11.5 in. He analysed the turnings; there was no segregation, since he had cut off 40 per cent. from the top of the ingot. The tool was 1 in. by $\frac{1}{2}$ in., the cut $\frac{3}{16}$ in., with traverse of $\frac{1}{15}$ in. It was used on a speed increment lathe, driven by a 40 horse-power electric motor. He started cutting at a speed of 20 ft. per minute, and increased the speed by 1 ft. per minute until the tool broke down. At the end the nose of the tool was at a low red heat. The breaking-down point was at the speed of 42 ft. per minute. He concluded by repeating that the object of his paper was to prevent the introduction into specifications of the Brinell hardness test to ascertain the efficiency of high-speed steels.

On the motion of the Chairman, Dr. Arnold was awarded a hearty vote of thanks for his contribution.

(To be continued.)

GRINDING-MACHINES.—No. XXIV.

By JOSEPH HORNER.

THE general scheme of table and wheel feeds embodies a ratchet-wheel and pawl as its basis, the coarser or finer feeds being controlled by the number of teeth passed by the pawl during one movement, when the reversing-lever is struck by a dog. The subject was treated in ENGINEERING on August 21, 1903, page 241, which may be supplemented by the following later designs.

A machine has been designed and built by the Brown and Sharpe Manufacturing Company which is remarkable in respect of the methods by which a self-contained drive has been worked out. From a simple countershaft driving to a single pulley on the machine all the movements are operated. The countershaft has just one loose and one fast pulley, and a driving pulley. This drives to a large pulley located at one end of the machine, from the shaft of which the wheel spindle, the work headstock, and the table traverse are all driven. Chain-driving is largely drawn on for transmission, and friction-discs for speed and feed changes. Before illustrating these details, it seems necessary to outline the general scheme of the machine. A plain grinding-machine of this design is shown by the photograph reproduced in Fig. 361, Plate XXXIX., being one which has a capacity for taking work up to 32 in. length by 6 in. in diameter. The drawing, Fig. 362 (on the same plate), is a rear elevation, and Fig. 363 a vertical transverse section of the machine.

The main driving-pulley, driven from the countershaft with a 3-in. belt, is seen at A, Figs. 361 and 362, where it drives a shaft running in two tapered roller-bearings bolted to the rear of the machine. A motor can be substituted for the countershaft drive. The shaft makes 900 revolutions per minute. Thence the spindle of the grinding-wheel B is driven with a 3-in. belt from a pulley C, Figs. 362 and 363, which occupies a central position between the roller-bearings. The changes in speeds of the wheel spindle are produced by substituting different pulleys, which, being split, can be interchanged without taking off the belt. Three of these are seen lying on the floor in the photograph, Fig. 361. The belt passes over two idler pulleys, D, E, Fig. 363, the bearings of which are supported in a swinging bracket F, which follows the transverse movements of the wheel stand, and so preserves the tension of the belt in all positions of the wheel The slack due to the differences in the diameters of the different pulleys put on the wheel spindle is taken up by adjustments made on the top idler-pulley E, which is provided with a separate adjustment.

The traverse movements of the table and of the work headstock are driven by sprocket-chains through a speed-gear case, seen uncovered in the photograph, Fig. 364. Its exterior is seen at G, in Fig. 362. The traverse movement of the table is driven by a sprocket H, Fig. 363, on the speed-case, which drives to the sprocket J on the table-traverse reversing mechanism, the latter being contained in a case that is enclosed in the bed of the machine at the front. The headstock is driven from the speed-case by a sprocket K to a double sprocket L, which is an idler, to a hardened splined sprocket M. A splined shaft N passing through this sprocket M, and supported in bronze bearings under each end of the work-table, drives (see Figs. 361 and 362). through a chain and sprockets enclosed, a telescopic shaft O and universal joints which transmit motion to the headstock chain. Means of adjustment are provided for these chains.

Another innovation besides that of the sprocket drives is the adoption of friction-discs for effecting changes in speeds and feeds. The drive from the main shaft to the sprockets in the speed-case, whence the drive to the headstock and table are effected, is transmitted through multiple friction-discs seen in the photograph of the open case, Fig. 364, while the shapes of the discs in section will be seen in Fig. 365. The advantages which these possess over gears are that the starting and stopping are done without shock, and the choice of a large range of speeds and feeds is available.

The main driving-shaft P in the gear-box, Figs. 361 and 364, is connected by the coupling Q to the shaft of the main driving-pulley A, seen in the rear elevation, Fig. 362, where the gear-box is marked G. Thence the shafts R and S, Fig. 364, are driven. Power is transmitted from the shaft P through the spur-gears seen in Fig. 364 to the shafts R and S at constant speeds, one set for effecting the table traverse, the other the revolutions of the work headstock. The shafts R and S each carry a series of hardened-steel discs *a* and *b* respectively, ground slightly convex, and engaging with another series of discs *c* and *d* having rims around their peripheries (compare with Fig. 365), so that they make contact with *a* and *b* around their peripheries only. The shafts R and S are mounted on swinging brackets T and U respectively, that are pivoted on the bearings of the main driving shaft P, and are swung inwards, or away from the centres of the rimmed discs *c* and *d*. As the frictional contact thus occurs in a range of varying radii, lesser or greater, the feed of the table and the speed of the work are varied.

Three levers with their dial Y, seen at the left of the machine in Fig. 361, control these movements. The lever seen uppermost, which is marked "Head," controls the rotation of the work, which ranges without break from 82 revolutions per minute to 412 revolutions per minute. The lever seen at the lower left hand, marked "Table," controls the rate of table traverse. The dial is graduated to read in inches per minute, and the range is from 13 in. to 181 in. per minute. The third lever at the right, longer than the others, serves to start and stop the work and the table simultaneously, and without stopping the grinding-wheel. The back of the dial Y is also seen at the upper right hand of Fig. 364. The brackets T and U are swung backwards and forwards by means of bevel pinions mounted at the foot of the inclined tube V, seen in Fig. 364. The lever marked "Head" operates the brackets U, U, which control the speeds of the headstock; the lever marked "Table" actuates the brackets T, T, which control the feed of the table. The long lever W, Fig. 364, starts and stops the headstock and table travel through a cam located at the foot of the shaft X. It acts through a lever which relieves the pressure applied to the discs *c* and *d* by the springs at *e* and *f*. It also applies brakes which bring the table and headstock to rest quickly.

The rows of figures round the dial Y are not visible in the photograph, but there are two rows, one indicating a slow series of table feeds, the other a fast series, the change from one series to the other being made by a lever. Notches round the edge indicate the large number of changes available. The changes of speed for the work and the table are independent of each other, so that combinations of fast and slow speeds are available. There are twelve indicated changes of work speed. Twenty-four indicated changes of table feed are available in two series, the slow series ranging from 13 in. to 69 in. per minute, the fast series from 36 in. to 181 in. per minute.

Oil is pumped over the gears and parts enclosed in the case G by a plunger-pump *g*, worked from the shaft P, Fig. 364, to a distributor at the top. An independent automatic cross-feed is included, by which the wheel can be fed in to the work without traversing the table. The advantage lies in work which is not so wide as the grinding-wheel. It is driven from the mechanism of the table traverse and it operates the ratchet mechanism of the regular automatic cross-feed.

The unique form of work-head is shown by Figs. 366 to 369. Of the dead-centre type, the work-driving plate, chain-driven, is secured to a sprocket which runs on tapered roller-bearings around a fixed spindle, that carries the dead-centre. Wear of the bearings is taken up by the nuts at the front. The drive to the headstock, as stated, is under the control of the lever marked "Head" around the disc Y in Fig. 361, driving, as already described, to the universal jointed shaft O, Figs. 361 and 362. The position of this shaft is seen in Fig. 367, whence a chain drives to the sprocket-wheel Z on the headstock, Figs. 367 and 369. This is carried on the outer casing *h* of the roller-bearings *j*, the inner paths of which are forced on the fixed spindle A A, Fig. 369. The driver-plate B, B is screwed to the casing *h*. The driver C, C (compare with Fig. 366) is of adjustable type, pivoting, and clamped with a bolt in a slot. The headstock is clamped by the bolt seen in Fig. 367. A good deal of detail may be noticed in these drawings, including the ample lubricating arrangements, table-slides, bed castings, and so on.

The automatic cross-feed of the wheel-head in the grinding-machine by the Cincinnati Grinder Company, of Cincinnati, Ohio, U.S.A., is shown by Fig. 370, Plate XXXIX. It comprises feed reversal and a positive stop. The lever A is struck by the trip-dogs B, and so reverses the table feed through the bevel gears and central clutch, and also operates the ratchet feed. The brackets with their dogs are carried in a dovetail on the front of the sliding-table, against which they are held with a lever clamp *a*. As is usual with most dogs now, they permit of running the table past the points of reversal, and readjust themselves after the table has returned, so that the original setting is not disturbed. Also they have screws, which provide for fine adjustment after their brackets have been clamped. The reversing-lever A controls the reversing nest of bevel-gears, and also actuates the cam-lever C, which, moving on the fixed cam-roll *b*, imparts movement to the connecting link D and the pawl E. The pawl E is attached to the plunger F. The connecting link D ties the cam-lever C to the vertical plunger F. The compression spring *c* contained in the plunger bracket G serves to raise the vertical plunger F. The throw of the pawl E is controlled by the adjusting-screw H, which operates as a limiting stop to the upward movement of the plunger F, and serves to vary the feed.

The sequence of operations in setting and using the feed is as follows: The trip-dogs B, B having been set to suit the required table travel, the pawl E is drawn clear to the position dotted at E^1. With the work and the wheel running, the cross-slide is fed by the hand-wheel J in the direction indicated by the full arrow until the grinding-wheel just comes into contact with the work. The table stroke is now stopped, and the pawl E is brought into the position shown by the full lines, when the pawl-tooth *d* will mesh with the teeth of the ratchet-wheel K. The pawl shield *e* is lifted, and the ratchet-shield *f* moved to the left until the pawl-shield *e* is immediately beyond the ratchet-teeth engaged by the pawl-tooth *d*, raising the pawl E to allow the pawl-shield *e* to pass. The pawl E, being returned to its position, rests, and rides free on the pawl-shield *e*, and is therefore inoperative.

The table stroke is now started. The thumb-knurl *g* is turned, which will cause the ratchet-shield *f* carrying the pawl-shield *e* to move away from the pawl E, and leave the pawl-tooth *d* free to engage with the teeth of the ratchet K, and so feed. The feed of one tooth will equal one eight-thousandth of an inch, with a reduction of the

diameter of the work of one quarter-thousandth of an inch (about one-sixth of the thickness of tissue paper). When the wheel has cleared the work, the diameter ground should be measured, and before another traverse is taken the thumb-screw *g* is turned again, once for each quarter-thousandth of reduction required.

When the work is ground to its final dimensions, the pawl E is thrown back to the position E_1, and without changing the position of the ratchet-shield *f*, the hand-wheel is turned one revolution in the direction of the dotted arrow. The finished article is removed and another inserted, and the same process repeated.

Hand-feeding is done after moving the ratchet-shield *f* to the left, until the hole *h* is brought opposite the plunger *j*, where it is locked by drawing the plunger into the hole by means of the pin *k*. The thumb-knurl *g* is now turned to the left to its limit of movement for each quarter-thousandth desired.

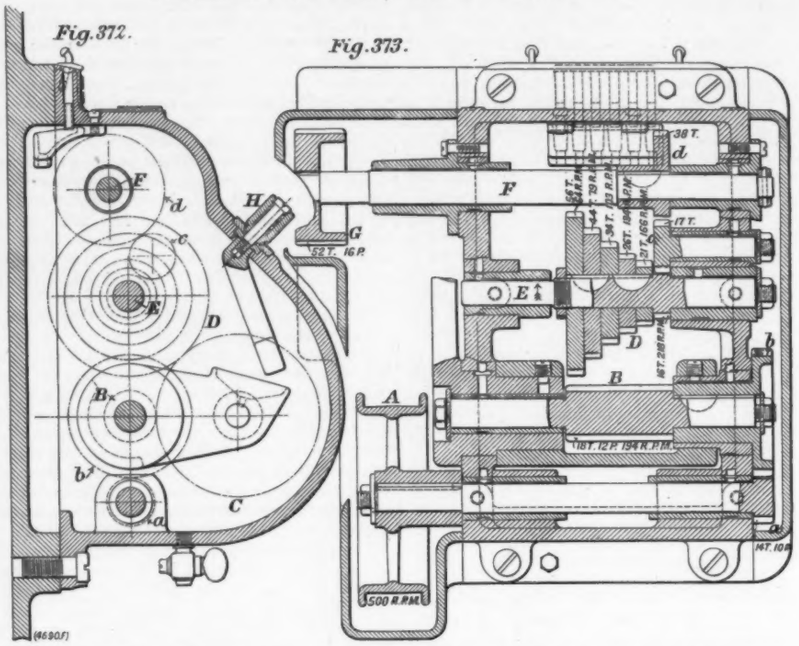
The positive stop is used when large numbers of pieces have to be ground in duplicate. The work is properly divided between two operations, roughing and finishing respectively, the first being done on a number of pieces which are removed, and afterwards replaced for finishing. This affords also an opportunity for seasoning when any internal stresses that may be present may become relieved. To use the positive stop, a first piece is ground by the ordinary routine to the exact finished dimensions required, as tested by micrometer measurement. The table travel being then stopped, and the hand-wheel not being moved, the ratchet-shield *f* is moved to the left, and the plunger *j* advanced until the stop-block *l* is brought into gentle contact with it, and the thumb-knurl *m* is then tightened, so locking the ratchet-shield *f* to the ratchet K, and with the plunger *k* forming a stop to the advance of the cross-slide. The hand-wheel J is now turned through one revolution in the direction indicated by the dotted arrow, the finished test-piece is replaced by a new piece, and the table stroke is started. The wheel is now drawn into the work by turning the hand-wheel J in the direction indicated by the full arrow, until the stop-block *l* comes into contact with the plunger *j*. The stroke of the table is then allowed to continue until the wheel has ceased cutting.

The "dwell" or "tarry" at the end of a table stroke is adopted now in a large number of machines. It can be thrown into and out of action, and the length of time of the tarry can be regulated to suit different conditions on different pieces of work. In the Cincinnati machines the amount is regulated by a clutch connection A, shown in Fig. 371, Plate XXXIX., the claws of which are stepped and tapered to permit of their being set more or less deep in engagement. For instant return at the points of reversal, the teeth bottom, while the farther the teeth are drawn out the longer will be the dwell at the end of the stroke. The depth of engagement is regulated by the clutch-lever B, set by means of the limiting screw and check-knurl C. To prevent the claws from disengaging unless pulled out by hand, a screw D is provided. This tightens the plunger E on the shaft F that carries the clutch-lever B. If the latter operates too freely, and allows the clutch jaws to fall out of mesh, the screw D must be tightened a little more. When the clutch A is lifted out of engagement with its lever, the table drive is disengaged, and the table may then be moved by its hand-wheel G.

A variable table-feed mechanism, driven from a single-speed pulley by the Brown and Sharpe Manufacturing Company, is shown by Figs. 372 and 373, annexed.

The feeds are derived from the pulley A, making 500 revolutions per minute. Its shaft carries at the opposite end the pinion *a*, driving the gear *b* on the shaft which carries the long pinion B. Connection is made from this by the long swinging gear C, outlined only in the end view, Fig. 372, with either one of the nest of six gears D, which drive the shaft E at rates ranging from 64 revolutions per minute to 218 revolutions per minute. These are transmitted through the pinion *c* to the gear *d* on the shaft F, which carries the final gear-wheel G. The swinging-gear C is located vertically by a lever moving over a quadrant (not shown) and another H, which sets it in longitudinal relations.

DETAILS OF GRINDING MACHINES.



FIGS. 372 AND 373. VARIABLE TABLE FEED MECHANISM; THE BROWN AND SHARPE MANUFACTURING COMPANY, PROVIDENCE, RHODE ISLAND.

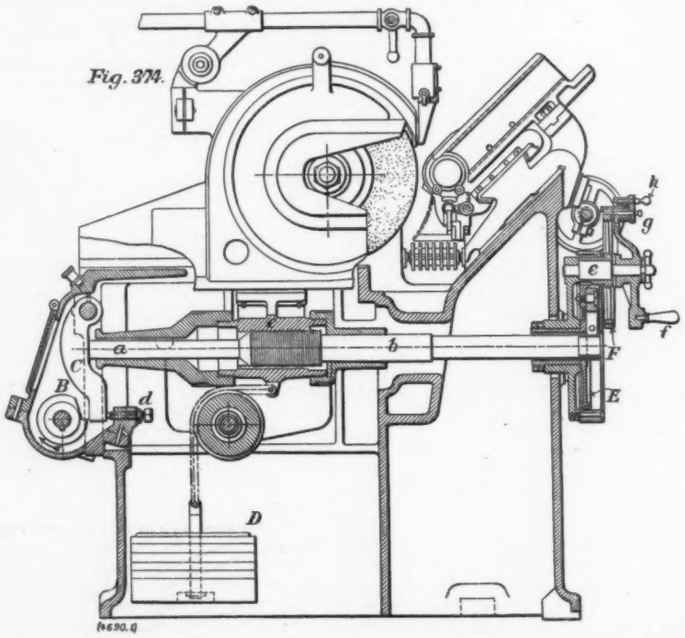


FIG. 374. NORTON FINE CROSS-FEED; THE NORTON GRINDING COMPANY, WORCESTER, MASS., U.S.A.

Fig. 374, above, is a transverse section through a Norton automatic grinder, to show the method by which the fine adjustments of the wheel towards and from the work are effected. A shaft carries the cam B, which makes contact with the lower end of the lever C, whence the wheel-slide is reciprocated under the control of the rods *a* and *b* through the nut *c* attached to the bottom of the wheel-slide, against the pull of the weight D. The stop-screw *d* is set to fix the maximum amount of travel of the wheel. The fine adjustment is effected by the finely-threaded screw on the end of *b*, which engages on the nut *c*. The screw and its nut provide for the fine adjustments both for precision grinding and to compensate for wear. The rod *a* moves endlong only, being splined. The screwing of the rod *b* into the nut *c* is the means of compensation for wear. Two flats at the extreme right of *b* receive clamps, which are fastened to the gear E. This gear is revolved directly by the pinion *e* and hand-wheel *f*, to effect rapid adjustment. For making fine adjustments, the handle *g* turns a pinion that meshes with the gear F in one with *e*. *h* is a pin which enters holes in a division-plate on the axis of the pinion. A movement of the pin from one hole to the next adjusts the wheel-slide by 0.00005 in.

With these illustrations we conclude the present series of articles. Although the subject has been treated only at moderate length, bearing in mind the remarkable scope covered by grinding practice to-day, yet we trust that no important development has been omitted.

THE CORROSION OF IRON AND STEEL.

*The Influence of Carbon and Manganese upon the Corrosion of Iron and Steel.**

By Sir ROBERT HADFIELD, F.R.S., and J. NEWTON FRIEND, D.Sc.

FOR many years there has been a considerable amount of interest centred round the problem as to whether or not the presence of manganese in steel increases its liability to corrosion. The answer to this question was given in the affirmative by Berthier,† Siemens,‡ Snelus,§ and more recently by Finkener,‖ and others. In 1905, Cushman¶ gave the results of an extensive study of the causes leading to the corrosion of wire fences in America, and drew attention to the fact that the majority of the wires that had withstood corrosion reasonably well exhibited upon analysis a low manganese content, namely, less than 0.2 per cent. On the other hand, the more corroded specimens generally contained some 0.5 per cent. of manganese. These results could not be regarded as conclusive evidence that alloyed manganese tends to increase the corrodibility of steel, for two reasons, namely :—

1. The sulphur content of the wires was apparently not determined. This was an unfortunate oversight, for sulphur is well known to have a highly deleterious effect upon the corrodibility of iron; and if in the 0.5 manganese steels the sulphur content was proportionately high, it is easy to understand that the increased manganese, present mainly as sulphide, would greatly assist corrosion. In other words, the reputation of the manganese would be suffering by its bad companionship.

2. Cushman himself observed that there were certain well-defined exceptions to his rule, for a few specimens of wire of 0.5 and even higher manganese content resisted corrosion quite well. This clearly indicates that some other factor was at work and lends support to our first argument.

Three years later Heyn and Bauer,** in the course of their monumental researches into the general problem of corrosion, determined the effect of increased manganese content upon the corrodibility of a kind of cast iron, containing approximately 3.5 per cent. of carbon, 2.5 per cent. of silicon, and 0.07 per cent. of sulphur and of phosphorus. The irons were exposed to tap-water with the following results :—

Manganese, per cent.	0.46	0.70	0.99	1.90	2.83	3.08
Relative corrosion ...	100	92	100	94	96	89

Unfortunately no parallel experiment was carried out with iron containing only traces of manganese; nevertheless the results clearly show that the presence of upwards of 1 per cent. of manganese tends to protect iron from corrosion in tap-water.

A considerable number of alloys of manganese and iron were tested in 1912 by Aston and Burgess†† for corrodibility, but the results showed remarkable variation, and it is difficult to base any satisfactory conclusion upon them. An interesting research carried out by Desch and White‡‡ on the micrographic corrosion of steels containing manganese led to no definite results, the authors incidentally referring to the extreme difficulty of obtaining commercial steels of varying manganese content, but in which the other alloying elements are constant. Four steels, containing varying quantities of carbon and approximately 0.9 per cent. of manganese, were tested by Aitchison§§ in various corroding media, but the number of specimens was too small to admit of any very useful conclusions being drawn.

The present research was therefore undertaken with a view to throwing further light upon this intricate problem. Of late years it has been repeatedly emphasised that different corroding media exert very different effects upon iron and steel, no one metal resisting all kinds of corrosion equally well. The authors considered it essential, therefore, to test the steels in a variety of ways, namely :—

1. By exposure to tap-water, which is the nearest laboratory analogy to the conditions experienced in the case of steel pipes submerged in spring or river water.

2. By exposure to sea-water.

3. By exposure to alternate wet and dry—a process that closely corresponds to the action of the weather in our uncertain climate, as well as to the conditions experienced by the water-line portions of structures half in and half out of rivers or canals, as, for example, canal lock-gates, the water-line of river steamers, and so on.

4. By exposure to two concentrations of sulphuric acid. These were fairly dilute, namely, 0.1 and 0.5 per cent. solutions respectively; for in nature one rarely has to deal with strong acids. The acid waters of mines, for example, are really very dilute in most cases, and it did not seem to the authors that a study of the action of more concentrated acid would be of any practical value.

Two different types of steel have been employed in this research, namely :—

1. Two series of carbon steels containing varying quantities of carbon, but the other alloying elements remaining very constant, save that in the first series the manganese content was less than 0.2 per cent., whilst in the second series it averaged 0.7 per cent.

2. The remaining steels, Nos. 19 to 35, contained 2 per cent. and upwards of manganese.

Both from a commercial and from a scientific point of view the results detailed in the sequel are of exceptional importance, and serve to throw a flood of light upon the puzzling discrepancies observed by earlier workers upon the behaviour of steels towards acids in the so-called acceleration tests, and their entirely different attitude towards neutral corroding agencies, such as tap-water and weather.

METHOD OF EXPERIMENT.

The method of experiment was precisely similar to that already detailed in previous contributions,* and was briefly as follows :—

The individual pieces of steel were cylindrical in shape, measuring 0.75 inch in height and 0.5 inch in diameter. Their weight was approximately 18 grammes. In the tap-water, sea-water, and acid tests the metals were placed on wax discs in glass beakers of 450 cub. cm. capacity, each beaker containing only one disc and one piece of metal. Three hundred and fifty cub. cm. of liquid were now added, and the beakers placed in a dark cupboard, undisturbed for three, four, or eight months, according to circumstances, except in the case of the acid tests, in which case the liquid was frequently renewed, in order to ensure the constant presence of a great excess of acid. In the sea-water tests a 3 per cent. solution of Tidman's sea-salt was employed. In the alternate wet and dry tests the metals were placed in a ring, on wax discs, in a large cylindrical galvanised iron bath, of diameter 22 in., the bath being alternately filled and emptied by a syphon arrangement. The water entered and left by tubes fixed in the centre of the bath in order to effect a perfectly uniform distribution of the fresh aerated water.†

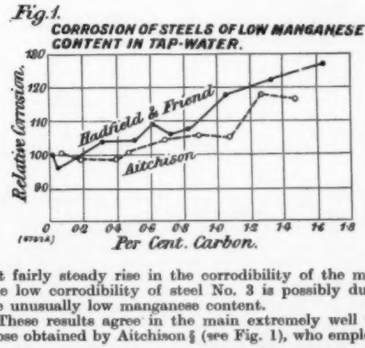
All the experiments in any one series were carried out at precisely the same time. It is important to emphasise this, for the rate of corrosion of iron is greatly influenced both by the temperature and by the amount of oxygen dissolved in the corroding media; in other words, by the height of the barometer. By carrying out all the tests at the same time, however, minor fluctuations of temperature and pressure do not need to be considered, provided all the specimens receive identical treatment. The results obtained are given in Tables I. to IV.‡ The steels were prepared at the Hecla Works, Sheffield. The carbon steels (Nos. 1 to 18) were heated to 775 deg. Cent. and cooled slowly in order to avoid any disturbing effects due to strain, &c. The manganese steels (Nos. 19 to 35) were quenched in water from 1000 deg. Cent. Analysis showed them to have the compositions given in Table V., page 446.

Inasmuch as steels rarely contain less than 0.2 per cent. or more than 0.8 per cent of manganese, it has been found convenient to deal with the results obtained in this research under three different headings. These comprise the study of steels containing (*a*) less than 0.2 per cent. manganese, (*b*) between 0.2 and 0.7 per cent. manganese, and (*c*) between 2 and 16 per cent. manganese.

A.—INFLUENCE OF CARBON ON IRON CONTAINING LESS THAN 0.2 PER CENT. OF MANGANESE.

1. *Tap-Water Experiments.*—In Table I. (steels Nos. 1 to 11) are given the results of exposing to the action of tap-water steels of carbon content ranging from 0.03 to 1.63 per cent., for two periods of three months. As these are very similar, a consideration of the total loss for the six months' exposure will suffice. It will be observed that the addition of carbon induces a gradual

Fig. 1.



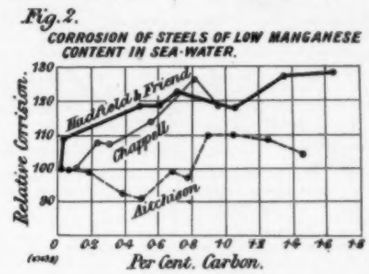
but fairly steady rise in the corrodibility of the metal. The low corrodibility of steel No. 3 is possibly due to the unusually low manganese content.

These results agree in the main extremely well with those obtained by Aitchison§ (see Fig. 1), who employed an analogous series of steels with carbon contents ranging from 0.07 to 1.46 per cent.

The slight maximum with the 0.6 per cent. steel and the subsequent rapid rise in corrodibility after the eutectic composition has been reached are particularly interesting points.

2. *Salt-Water Experiments.*—The results of the salt-water tests are given in Table II. (steels Nos. 1 to 11), and are compared with those obtained by Aitchison* and by Chappell,† who tested steels of similar composition. A slight maximum is observed with the 0.7 per cent. carbon steel. On the whole, the addition of carbon tends gradually to increase the corrodibility of the steel as in the tap-water tests, the corresponding curves in Figs. 1 and 2 showing a general resemblance. The results of Chappell, as far as they go, are very similar to those of the present authors. They also show a

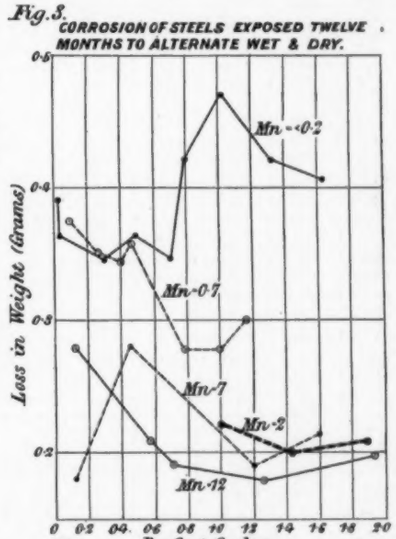
Fig. 2.



maximum with the 0.8 carbon steel, whilst Aitchison's maximum occurs with 0.89 to 1.05 per cent. carbon. There can be no doubt, therefore, that in the neighbourhood of the eutectic composition the metal shows a slight tendency to corrode more rapidly in sea-water than with less or with slightly more carbon. Further increase of carbon increases the corrodibility yet more. The initial fall in Aitchison's curve to a minimum with 0.5 per cent. carbon is not in harmony either with Chappell's results or with those of the present authors.

3. *Alternate Wet and Dry.*—These tests correspond most closely to the action of the weather upon steel, and are therefore particularly important in view of their bearing upon the durability of iron and steel structures exposed to aerial oxidation. These results are detailed in Table III. (steels Nos. 1 to 11), and shown graphically in Fig. 3. As in the tap-water and sea-water tests the

Fig. 3.



curve exhibits a maximum point, but in the neighbourhood of 1 per cent. of carbon.

4. *Acid Tests.*—Two sets of acid tests were carried out, namely, with 0.1 and 0.5 per cent. sulphuric acid respectively. The acid was in each case frequently renewed, in order that it might always be present in great excess. The results are given in Table IV. (steels Nos. 1 to 11), and the results with 0.5 per cent. acid are shown graphically in Fig. 4, those with the weaker acid being very similar. It will be observed that the solubility of the metal rises rapidly with increase of carbon, a maximum being attained when the metal has approximately the eutectic composition. The steel then dissolves twelve and a half times as rapidly as the 0.03 carbon steel (mean of steels Nos. 1 and 2). The solu-

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* Paper read before the Iron and Steel Institute, Thursday, May 4, 1916.

† See Mallet, British Association Reports, 1838, p. 265.

‡ Journal of the Iron and Steel Institute, 1878, No. I., page 425.

§ *Ibid.*, 1881, No. I., page 66.

‖ *Mitteilungen aus der königlichen technischen Versuchsanstalt*, Berlin, 1897, vol. xv., page 277.

¶ U.S. Department of Agriculture, Farmer's Bulletin, No. 239, 1905.

** *Mitteilungen aus dem königlichen Materialprüfungsamt*, Berlin, 1908, vol. xxvi., page 1.

†† Eighth International Congress of Applied Chemistry, Washington, September, 1912.

‡‡ Journal of the West of Scotland Iron and Steel Institute, 1914, vol. xxi., page 176.

§§ Transactions of the Faraday Society, 1915, May and December.

* See Journal of the Iron and Steel Institute, 1915, No. I., page 353.

† See diagram, Journal of the Iron and Steel Institute, 1912, No. I., page 253. ENGINEERING, May 31, 1912.

‡ The demands upon our space compel us to omit the Tables I. to IV. given in this paper, but the results contained in the tables are shown graphically in the diagrams which we reproduce.

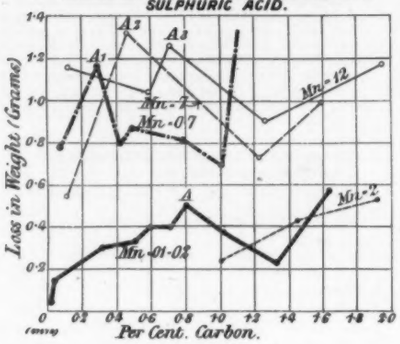
§ Transactions of the Faraday Society, 1915, December. In drawing the curves in Fig. 1 the corrodibility of Aitchison's metal of lowest carbon content is taken as 100, and the other corrodibilities expressed accordingly. Similarly, the mean of steels Nos. 1 and 2 is taken as the standard of comparison of the present authors' work.

* Transactions of the Faraday Society, 1915, May.

† Journal of the Iron and Steel Institute, 1912, No. I., page 270. The results with annealed steel are chosen.

bility then falls, to rise again later to fourteen times that of the 0.03 carbon steel, when its carbon content is 1.63 per cent. Clearly, therefore, the best iron to resist acid attack is that containing only traces of carbon. It is interesting to note that the curve, in showing maximum and minimum points, is precisely analogous to the corresponding curves in Figs. 1 and 2, representing

Fig. 4.



the corrodibility of the steels in tap-water and sea-water respectively. This analogy is all the more striking in view of the remarkable results obtained under similar conditions with steels containing approximately 0.7 per cent. of manganese, to be described in the sequel.

In his researches Aitchison used 1 and 10 per cent. sulphuric acid solutions; but the results can hardly be regarded as comparable with those under consideration, for the acid was not renewed, and a simple calculation based on the data supplied in the original memoir* suffices to show that the acid must all have been neutralised before the conclusion of the experiments. Consequently Aitchison's figures represent the mean result of

TABLE V.—*Analyses of the Steels.*

Steel No.	Carbon	Manganese.	Silicon.	Sulphur.	Phosphorus.
1	0.03	0.08	0 009	0.056	0.005
2	0.03	0.015	0.01	0.016	0.005
3	0.04	trace	0.07	0.005	0.004
4	0.31	0.06	0.15	0.051	0.037
5	0.50	0.04	0.05	0.082	0.050
6	0.62	0.11	0.21	0.04	0.04
7	0.71	0.13	0.22	0.03	0.06
8	0.81	trace	0.037	0.04	0.04
9	1.05	0.09	0.22	0.04	0.04
10	1.34	0.19	0.11	0.02	0.02
11	1.63	0.14	0.19	0.02	0.02
12	0.12	0.58	0.21	0.06	0.06
13	0.28	0.57	0.06	0.08	0.06
14	0.40	0.64	0.03	0.06	0.056
15	0.48	0.75	0.12	0.07	0.07
16	0·79	0.84	0.06	0.066	0.057
17	1.01	0.89	0.08	0.056	0.047
18	1.17	0·57	0.05	0.02	0.02
19	1.00	1.94			
20	1.44	1.93			
21	1.90	2.00			
22	0.12	6.67			
23	0.45	6.80			
24	1.24	7.16			
25	1.60	7.48			
26	0.04	11.41	0.1-0.2	0.03	0.04
27	0.58	11.09			
28	.71	11.92			
29	2.25	11.67			
30	1.94	12.20			
31	1.10	3.89			
32	1 00	6.87			
33	0.98	10.33			
34	1.11	11.93			
35	1.16	15.6			

exposing the steels first to acid of constantly falling strength, ending, secondly, with a neutral corroding medium. The results, therefore, cannot be taken seriously. The work of Chappell† is not open to the same objection. Working with 1 per cent. sulphuric acid solution the same general type of curve was obtained with the normalised, rolled, and annealed specimens. The maximum solubility of the steels, however, was found to occur with approximately 0.2 per cent. of carbon, and the minimum at about 0.4 per cent. carbon. Further increase of carbon yielded a general but somewhat irregular rise in solubility. This, presumably, is simply another way of stating the fact, for which a good deal of evidence has recently been accumulated, that as regards the resistance to attack for each concentration of acid there is a corresponding optimum carbon content, the probability being that no one steel will exhibit equal resistance to all concentrations of acid. This has been well illustrated in the case of cast iron.‡

* *Loc. cit.*

† *Chemical News*, 1911, vol. civ., page 155.

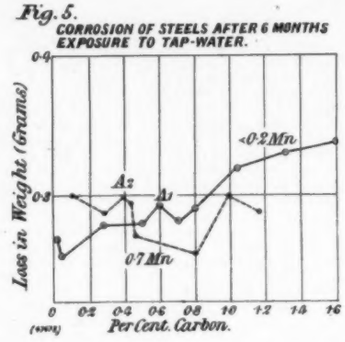
‡ Journal of the Iron and Steel Institute, 1915, No. I., page 353.

B.—THE INFLUENCE OF SMALL QUANTITIES OF MANGANESE (APPROXIMATELY 0.7 PER CENT.) UPON THE CORRODIBILITY OF CARBON STEEL.

The steels that have been discussed in the foregoing columns have possessed very low manganese contents, in no case exceeding 0.19 per cent. Since, however, ordinary commercial steels frequently contain as much as 0.5 to 0.7 per cent. of manganese, it seemed important to determine whether or not this amount would affect to any appreciable extent the corrodibility of the metal. The problem is one which has been discussed by many authorities, the opinions voiced being very conflicting in character. The difficulty has lain in obtaining steels containing the requisite quantities of carbon and manganese for a comprehensive study.

1. *Tap-Water Experiments.*—The results are given in Table I., Series II., and are shown graphically in Fig. 5.

Fig. 5.



It appears that the presence of approximately 0.7 per cent. of manganese in the steel has not a very important effect upon the corrodibility of the metal. The steels with up to about 0.5 per cent. of carbon appear to be slightly more corrodible than those of corresponding carbon content, but containing less than 0.2 per cent. of manganese. With a carbon content of 0.5 per cent. onwards the 0.7 manganese steels have a slight advantage over the 0.2 manganese steels. It is interesting to note that both curves are of the same type, possessing a maximum and minimum. The presence of the additional manganese appears to have shifted the maximum point to the left (from A1 to A2, Fig. 5).

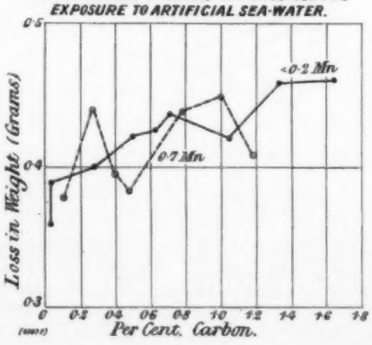
2. *Salt-Water Tests.*—(See Series II., Table II., and Fig. 6.) In the sea-water tests the curves again show a maximum and a minimum. The difference in the relative corrodibilities of Series I. and II. is again not very great.

3. *Wet and Dry Tests.*—(See Series II., Table III., and Fig. 3.) In these tests the presence of approximately 0.7 per cent. manganese is seen to be a very decided protection against corrosion, particularly when more than 0.5 per cent. carbon is present. The results thus closely agree with those of the tap-water tests.

4. *Acid Tests.*—These results obtained in the acid test are of unusual interest and importance (shown in Table IV., and graphically for 0.5 per cent. acid, in Fig. 4). It will be observed that the curve for the 0.7 manganese steels again exhibits maximum and minimum points, these occurring with smaller quantities of carbon than the corresponding points on the 0.2 manganese steel curve. But the most striking feature is the enormously increased rate of solution of the 0.7 manganese steels, amounting to upwards of 300 per cent. of that of the 0.2 manganese steels of corresponding carbon content.

This is a point of very great practical importance, for manganese may be regarded as a normal constituent

Fig. 6.



of steel when present in small quantities. Now in commercial steels the percentage varies widely within the limits of 0.2 to 0.7 per cent., and one can now readily understand why such varying results should have been arrived at when samples of different brands of steel have been subjected to acid acceleration tests.* For pipes or structures destined for exposure to acid vapours or liquors low carbon steels with a manganese content of less than 0.2 per cent. are eminently desirable if rapid corrosion is to be avoided. The lower the carbon content the better.

This result is all the more astonishing when we remember that other alloying *metals* (this remark does not apply to non-metals) such as nickel, tungsten, molybdenum, &c., exert very little influence upon the corrodibility of the steel unless present to the extent of some 3 or more per cent. The powerful influence of the additional 0.5 per cent. of manganese to the steels of Series I. has thus produced an entirely unexpected result.

C. THE CORRODIBILITIES OF STEELS CONTAINING FROM 2 TO 16 PER CENT. OF MANGANESE.*

1. *Tap-Water Experiments.*—The results of these are given in Table I. (Series III. to VII.) and in Figs. 7 and 8, from which it is evident that addition of more than 2 per cent. manganese to the steel very appreciably reduces its corrodibility, particularly when the steel has a carbon content of upwards of 0.8 per cent.

2. *Sea-Water Tests.*—A consideration of Figs. 8 and 9, which embodies the results of Series III. to VII in Table II., shows very clearly that an increase of manganese very materially decreases the corrosion, particularly in the case of the steels containing upwards of 0.6 per cent. of carbon.

In the case of the 1.0 per cent. carbon steel the greatest retarding effect of the manganese appears to be exerted with 2 per cent. of that element. The similarity of the

Fig. 7.

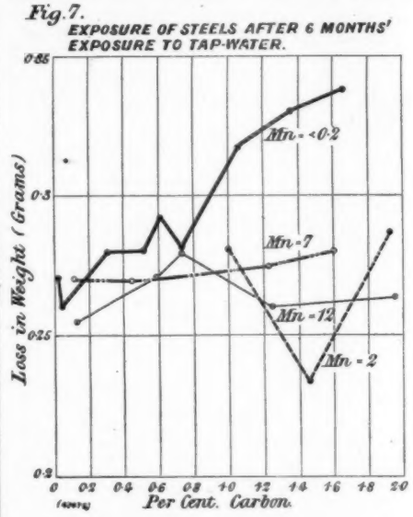
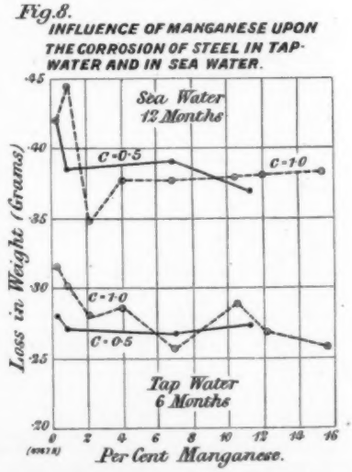


Fig. 8.



corrodibilities of steels 30 to 35, containing 4 to 15.6 per cent. manganese, is worthy of note.

3. *Wet and Dry Tests.*—The results of these tests are very clearly shown in Fig. 3, and point to the fact that the presence of upwards of 2 per cent. of manganese has a powerful effect in reducing corrosion, particularly in the presence of more than about 0.5 per cent. of carbon.

4. *Acid Tests.*—The results obtained with acids are very interesting. There can be no doubt that the presence of manganese enormously increases the rate of solution of the steel. In the case of the 0.1 per cent.

* In considering the results of Series VI. and VII. in Tables I. to IV. it must be remembered that steels 5, 15, 9, and 17 had not received the same thermal treatment as the other steels in the series, as already explained. (See concluding note on page 447.)

sulphuric acid the maximum effect is approximately reached with 0.75 per cent. manganese in the 0.5 carbon steel, and with 2 per cent. manganese in the 1.0 carbon steel, the solubilities remaining very uniform as the percentages of manganese are still further increased (Fig 10).

On the other hand, the 1.5 per cent. acid yielded somewhat irregular results, although in every case (except steel No. 19) the solubility is greatly enhanced by the addition of manganese. In this connection it is interesting to observe that the curves indicating the effect of rise of carbon on the manganese steels (Fig. 4) in every case tend to yield a maximum and minimum, precisely as has been repeatedly observed for corrosion results in neutral solutions.

It will be noted that in the 0.5 per cent. acid the 2 per cent. manganese steels do not appear to differ very greatly in solubility from the 0.2 per cent. manganese steels. In the weaker acid, on the other hand, the 2 per cent. steels behave like those containing 12 per cent. of manganese. This may perhaps indicate that for each concentration of acid an optimum manganese content exists possessing a minimum solubility.

The different effects exerted by varying concentrations of sulphuric acid upon manganese steels as indicated above is well illustrated by the results obtained by Cushman and Hadfield,* who exposed a series of steels to the action of 20, 25, and 50 per cent. acid respectively, with the following results :—

Steel No.	Carbon.	Manganese.	Heat Treatment.	Loss in Weight per Sq. Cm. 1 Hour. 20 per Cent. H_2SO_4 (Cushman).	1.5 Hour. 25 per Cent. H_2SO_4 (Hadfield).	3 Weeks. 50 per Cent. H_2SO_4 (Hadfield).
2229	0.29	0.48	900° oil, 790° F.,* 540° F.	0.0036	0.0118‡	0.0358
2020 L	0.28	1.40	940–505, 725° F	0.0044	—	0.0432
2228	0.52	0.06	1100° air, 775° F.	0.0042	0.0162	0.0357‡
2228	0·52	0.06	940° oil, 615° W.†	0.0042	0.0140‡	0.0447‡
1618–2	0.54	1.03	910° oil. 615° W.	0.0042	0.0115‡	0.0763

* F = Cooled in furnace from temperatures given.
† W = Quenched in water from the temperatures given.
‡ Mean of two results.

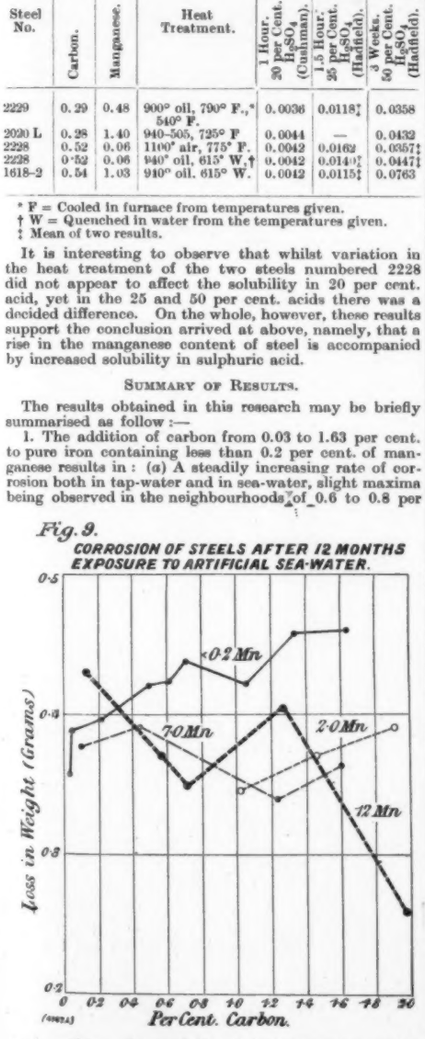
It is interesting to observe that whilst variation in the heat treatment of the two steels numbered 2228 did not appear to affect the solubility in 20 per cent. acid, yet in the 25 and 50 per cent. acids there was a decided difference. On the whole, however, these results support the conclusion arrived at above, namely, that a rise in the manganese content of steel is accompanied by increased solubility in sulphuric acid.

SUMMARY OF RESULTS.

The results obtained in this research may be briefly summarised as follow :—

1. The addition of carbon from 0.03 to 1.63 per cent. to pure iron containing less than 0.2 per cent. of manganese results in : (*a*) A steadily increasing rate of corrosion both in tap-water and in sea-water, slight maxima being observed in the neighbourhoods of 0.6 to 0.8 per cent. carbon. (*b*) An initial fall in corrosion, with a rapid rise to a maximum with 1.05 per cent. carbon in the wet and dry tests. (*c*) A rapid rise in corrosion to a maximum with 0.8 per cent. carbon when exposed to the action of dilute sulphuric acid. Clearly there is some difference of behaviour towards all the corroding media in the case of steels in the neighbourhood of the eutectic composition, the specimens showing either a tendency towards increased corrosion or else a most decided increase in corrosion.

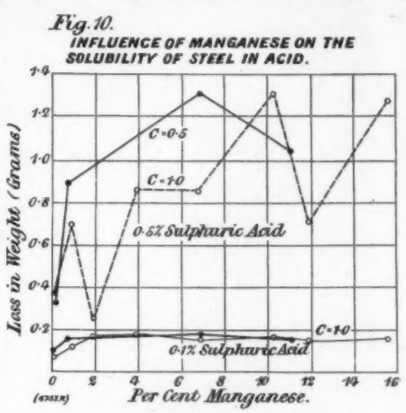
Fig. 9.



2. The addition of 0.7 per cent. of manganese to the above steels results in: (*a*) A very slightly increased corrosion in tap-water, sea-water, and in wet and dry tests with a carbon content up to about 0.4 to 0.5 per cent. From this point upwards the manganese, generally speaking, affords a slight protection, which is very decided in the wet and dry tests, but is not invariable in the sea-water tests. (*b*) An enormously increased corrosion in dilute sulphuric acid. This is particularly important, since in commercial steels the manganese content frequently ranges from 0.2 to 0.7 per cent., and it is evident that the latter are absolutely unsuited for exposure to acidified corroding media. Just as in the experiments with the steels of 0.2 per cent. manganese content, a point of maximum corrosion is observed ; but this always occurs with a smaller carbon content in the steels with 0.7 per cent. manganese.

3. By increasing the manganese content to 2 per cent. upwards: (*a*) The corrodibility in neutral solutions is greatly decreased, particularly when the carbon content exceeds 0.5 per cent. (*b*) The corrodibility in dilute sulphuric acid is greatly enhanced.

Fig. 10.



In conclusion, the authors desire to emphasise the fact that they have, in the foregoing, confined themselves exclusively to a consideration of the actual results obtained with the steels without in any way considering the theoretical reasons for the observed phenomena. The facts and records of the experiments are independent of any theoretical explanations of them. At the same time it is desirable to emphasise the fact that the theoretical explanations cannot be as simple as might appear at first sight, for the manganese, at any rate in the manganese steels proper, exists not merely as solid solution, but also in part as carbide. Again, it must be borne in mind that steels 1–18 had received a different heat treatment from the others, those with high manganese content (Nos. 19–35) having been quenched in the manner usual for such steels when used for commercial purposes. Not only, therefore, are the chemical compositions different in the two sets of steels, but their physical states are not identical. Any theory advanced by way of explanation of the authors' results, therefore, must take all of these points into consideration.

* Transactions of the Faraday Society, 1916, vol. ii., part 2.

BRAZIL AND ARGENTINA.—The British Bank of South America, Limited, has issued a report based upon information, dated March 15, which it has received from its branches in both countries. In regard to Brazil, it is stated that there is every prospect of crops being abundant. The situation in São Paulo is considered very sound. Stocks of merchandise are small, and as a consequence there is a demand for imported goods, and all that arrive are easily disposed of in spite of higher prices. The large commercial houses in England and the States who send out agents are doing well, as their travellers find but little competition. The difficulty is rather in the execution than in the obtaining of orders. With reference to Argentina, the report adds that all articles of import are in strong demand, but supplies are erratic, and importation, though increasing, is not on a scale sufficient for the country's needs.

NORTHERN TERRITORY OF AUSTRALIA.—The Australian Federal Government has received a report from the head of the Department of External Affairs (Mr. Atlee Hunt) upon the Northern Territory. Mr. Hunt states that the possibilities in regard to gold are good, while there are strong possibilities of the tin fields becoming profitable if the necessary capital is made available. The provision of capital would also enable the pastoral industry to assume great dimensions. So far the attempts made to establish settlers on the land have not produced very satisfactory results. Mr. Hunt advises that settlers should be encouraged to go there by the offer of liberal terms, but that they should not be bustled into premature occupation. Unless new and rich mining fields are discovered, it is submitted that the only course open is to wait until in the natural course of things the trend of population moves gradually northward, in the meantime carefully fostering any indications of new and profitable industries that may expose themselves. The Administrator of the Northern Territory (Prof. Gilruth) has expressed himself as in agreement with Mr. Hunt on all the points mentioned.

FOREIGN ENGINEERING PROJECTS.

WE give below a few data on several foreign engineering projects, taken from the *Board of Trade Journal*. Further information on these projects can be obtained from the Commercial Intelligence Branch, Board of Trade, 73, Basinghall-street, London, E.C.

Argentina : The *Boletin Official* (Buenos Aires) of March 3 publishes a Decree approving plans drawn up by the Sociedad de Beneficencia de la Capital (Buenos Aires) for the construction of a new building for a children's hospital, at an estimated cost of 373,592 pesos currency (about 32,700*l*.).

Chile : The *Diario Oficial* (Santiago) of March 7 publishes a Decree, dated March 4, granting permission to Don Horacio Urrutia Gundian to instal electric light and power systems in the towns of Illapel, Salamanca, and Vicuña. The necessary works must be commenced within a period of six months from the date of the Decree and completed within a further 12 months.

Portugal : The *Diario do Governo* (Lisbon) of April 20 publishes a notice, issued by the Ministerio do Fomento, approving the general project for the sanitation of the town of Covilhã, one of the more important industrial centres of Portugal, and authorising the initiation of the respective works.

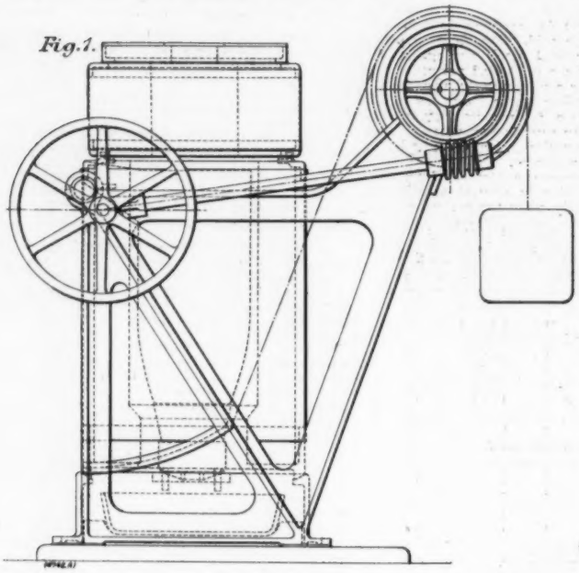
Spain : With reference to the notice on page 71 of the *Board of Trade Journal* of April 13, and to previous notices, relative to calls for tenders by the Municipality of Barcelona for the carrying out of street drainage and sewerage works in that city, it is announced in the *Gaceta de Madrid* of April 21 that tenders will be opened on May 27 at the Casa Consistorial, Barcelona, for the carrying out of additional works of a similar nature at a total estimated cost of 563,247 pesetas (about 23,000*l*. at current rate of exchange). The conditions of contract contain clauses to the effect that at the first competition the materials to be used will be confined, with certain exceptions, to products of Spanish manufacture, but that in the event of no decision being arrived at, a second competition, in which foreign products may be accepted, will then take place. In the latter event, Spanish products will have a 10 per cent. margin of preference over foreign. The *Gaceta* containing the conditions of tender and detailed particulars (in Spanish) regarding the works to be carried out and the materials to be used may be consulted by United Kingdom firms interested at the Commercial Intelligence Branch of the Board of Trade, 73, Basinghall Street, London, E.C.

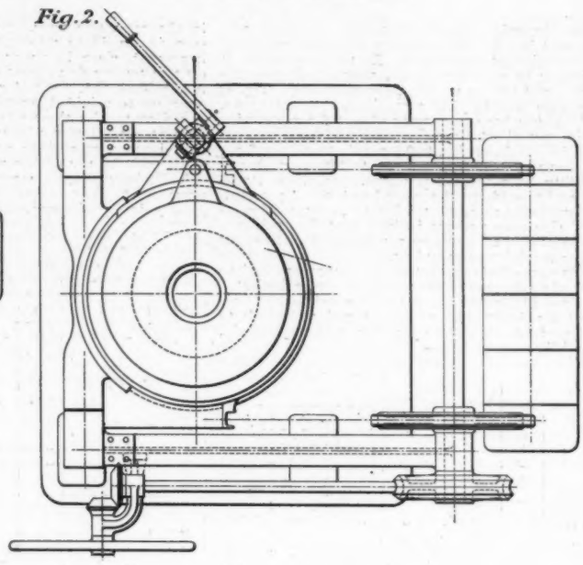
Uruguay : The *Diario Oficial* (Montevideo) of March 10 publishes the text of a Bill presented to the Uruguayan General Assembly relative to the utilisation of watercourses in the Republic for the purposes of irrigation works and the production of power. This measure is the result of investigations made by a Commission appointed in July, 1915, to report on the development of irrigation in Uruguay (see page 508 of the *Board of Trade Journal* of August 19 last). The Bill proposes that, for the purposes of constructing irrigation works and developing power, all the water-courses of the Republic, including those not suitable for navigation, shall be declared State property, as well as hydraulic forces in the country not yet exploited. An Irrigation Commission will be formed to decide upon projects for the carrying out of works, to administer the irrigation funds, to enter into contracts for the execution of the works, and to superintend the carrying out of the same, &c. When it is found that the total cost of each undertaking (including maintenance and working expenses, &c.) can be met by the water rate to be charged, the Executive shall decree the immediate execution of the works. This may only be done without specific legislative authority when the water rate for the minimum quantity of 2000 cub. m. (about 28,600 cub. ft. per acre) of water per hectare per annum does not exceed 3 pesos 50 cents (about 15s. 2d.). The works may be effected by administration or by private call for tenders among responsible firms. All machinery and materials for the construction and exploitation of the works and power-houses shall be admitted free of import duties. The Bill further proposes that for the realisation of the irrigation works the Executive may issue up to 1,500,000 pesos (about 325,000*l*.) in bonds of public debt, bearing 6 per cent. interest and 1 per cent. sinking fund. The Executive may also employ up to 200,000 pesos (about 43,300*l*.) annually from the general revenue.

JAPANESE INDUSTRIES.—Japan is doing much to meet the increasing demand for petroleum, and thousands of boxes have been shipped to Russia at high prices. Another Japanese industry which has profited by the war is that of rubber, especially rubber for motor tyres. The Japanese claim that their motor tyres are competing in the American markets, while inquiries have come to hand freely from British purchasers. Phenomenal profits have been obtained of late from Japanese shipping. The Nippon Yusen Kaisha has made a profit of 220,000*l*., as compared with 110,000*l*. in the previous financial year, and the company has declared a dividend of 15 per cent. The Toyo Kisen Kaisha, which had been working at a loss, accumulated last year a reserve of upwards of 1,000,000*l*., and paid a dividend of 12 per cent. Smaller shipping companies, as well as private owners, are also securing great profits. The Uchida Steamship Company, which has a capital of 25,000*l*., has paid a dividend of 600 per cent. for the past year. France, through her Ambassador at Tokyo, has made a special application to Japan for a charter of several steamers for transport service, and the Japanese authorities are doing what they can to respond favourably.

GAS-HEATED MELTING FURNACES.

CONSTRUCTED BY MESSRS. JOHN WRIGHT AND CO., ENGINEERS, BIRMINGHAM.





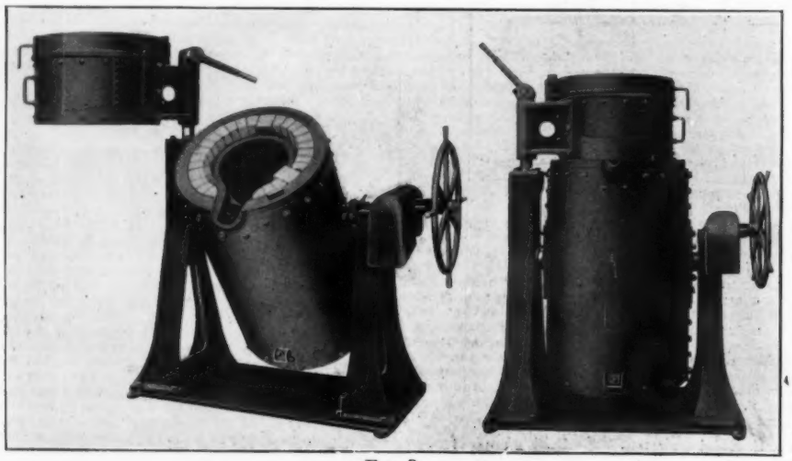


FIG. 3.

FIGS. 1 TO 3. CHAIN-TYPE AND CENTRAL-AXIS TILTING FURNACES.

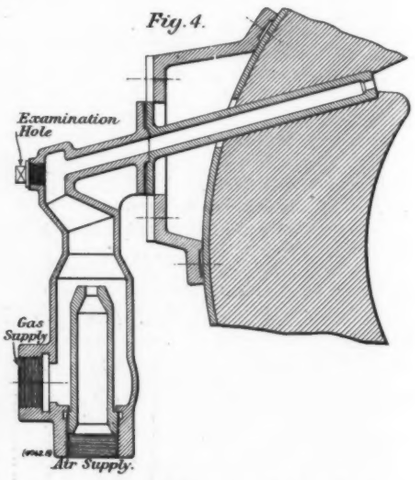


FIG. 4. THE WRIGHT-BRAYSHAW PATENT BURNER.

THERE are a number of questions in the heat treatment of metals which have received a satisfactory solution by the use of gas-heated furnaces, but the economical melting of metal in quantities is one which, until a comparatively recent time, had not been brought within the reach of gas apparatus, notwithstanding strenuous and persistent research work in this particular direction. Experiment alone, however diligent and well-informed, can seldom hope to achieve results so reliable as those which follow upon a combination of experiment on the part of a manufacturer with daily practical trial by actual users. In the associated works of Messrs. John Wright and Co., and of the Brayshaw Furnaces and Tools, Limited, both these conditions are found in combination and the experience and resources of these two concerns—both as regular users and as designers and makers—have been directed over a period of many years to the problem of metal-melting by gas. The work has involved exhaustive tests, with a numerous succession of special designs; and, as can well be understood, it has also meant great expenditure in research. The final result is the introduction of a new burner—the Wright-Brayshaw—which places gas in a position to compete most favourably with coke in the melting of metals in crucibles of capacities up to 600 lb. of brass.

A furnace equipped with this burner, and handled by workmen having no experience or training in the use of gas furnaces, has melted brass with a gas consumption under 1½ cub. ft. per lb. of metal melted, a lower working result than any substantiated figures for ordinary daily working which the makers have hitherto heard of, and which points to a complete revolution in metal-melting practice.

The crucible furnaces are supplied in three types. The one we illustrate in Figs. 1 and 2 was introduced some years ago in order to provide a furnace the pouring point of which should remain constant throughout the action of the whole tilting movement. In this type the trunnions are fixed on an axis adjacent to the pouring-lip of the crucible, and the bottom part of the furnace is raised by chains operated by means of a hand-wheel geared down to a shaft carrying toothed sprocket wheels. The ends of the chains are fastened to the bottom of the furnace body, and the weight of the furnace is balanced by a suitable counter-weight, so that when the hand-wheel is turned the furnace is tilted on its axis without the pouring point being shifted. Figs. 1 and 2, illustrating this type of furnace, merely show the arrangement for tilting, but the furnace is fitted with a preheater and cover similar to the centrally-mounted tilting type shown in Fig. 3.

A very important feature is the arrangement for slagging and cleaning out the bottom of the furnace, and for collecting the metal in the case of crucible breakage. The furnace is designed with a special semi-open case, through which the spilled metal passes into a suitable receptacle. The furnace can be cleaned out from the bottom without removing the pot. The chains are so designed that either will take the full load, making the mechanical working absolutely safe. The body is of mild steel, and thus escapes that liability to cracking which is not always avoidable even with the best cast iron.

Another type of tilting furnace is illustrated in the view, Fig. 3; in this type the body is mounted on trunnions fixed centrally to the furnace body. By operating a large hand-wheel connected to bevel and worm gears, the furnace is tilted for pouring the metal into ladles for casting. A top cover, fitted with a brick-lined preheater, is mounted on a steel pillar on one side of the frame. When the furnace is in its upright position the cover fits on top of it; a lever and cam device enable the cover to be slightly raised, and to swing clear of the furnace body when pouring has to be carried out. A similar cover is fitted to the furnace shown in Figs. 1 and 2. Fig. 4 illustrates the Wright-Brayshaw burner, to which special reference is made in the foregoing.

The stationary type of furnace is designed to stand in a pit either singly or in batteries; it is made suitable for crucibles having capacities up to 250 lb. of cupro-nickel or 300 lb. of brass. In this furnace the crucible is lifted out for pouring. The view in Fig. 5, on page 449, shows a battery of stationary furnaces of the pit type, fitted with Wright-Brayshaw air-blast burners.

We illustrate in Fig. 6 Messrs. Wright's "Lopress" regenerative annealing furnace, which is interesting in that the handling and adjustment are most simple, allowing the securing at will of a "reducing," "neutral,"

GAS-HEATED MELTING AND ANNEALING FURNACES.

CONSTRUCTED BY MESSRS. JOHN WRIGHT AND CO., ENGINEERS, BIRMINGHAM.

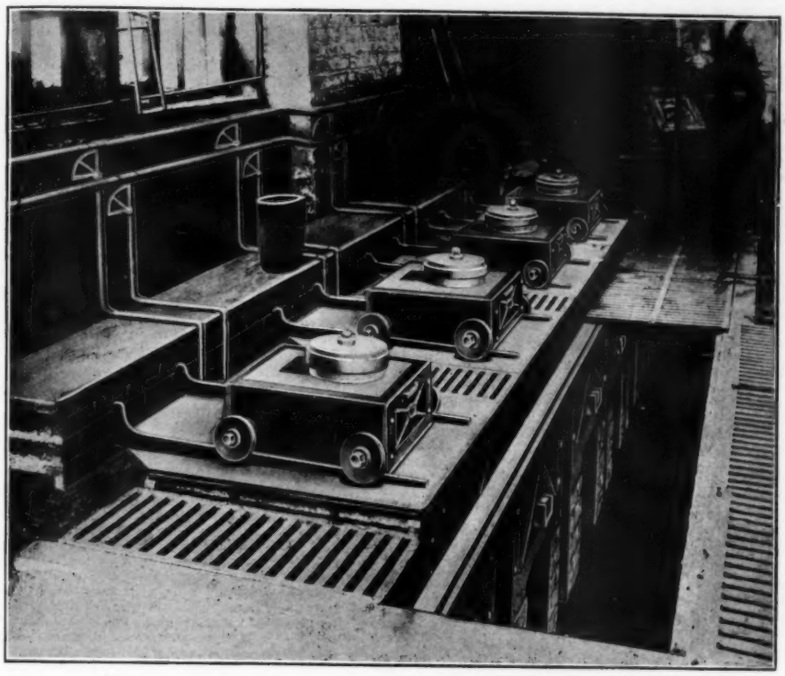


FIG. 5. A BATTERY OF PIT-TYPE CRUCIBLE FURNACES.

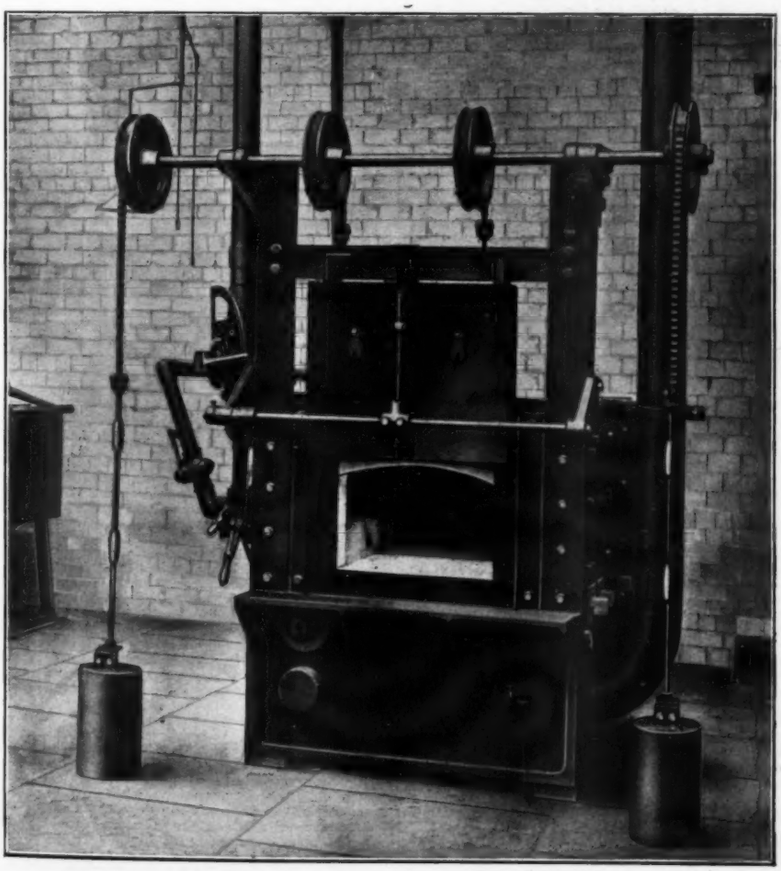


FIG. 6. THE "LOPRESS" REGENERATIVE OVEN FURNACE.

or "oxidising" atmosphere. The "greasy" flame so essential for annealing, and hitherto so difficult to obtain with gas, may be produced to perfection in this furnace. Gas is used at the ordinary town pressure, and air at 2 in. to 4 in. water-gauge pressure, provided by a simple fan. The air supply is subjected to true regenerative action, as distinguished from mere preheating by a cold-air jacketing arrangement. A special feature of the construction is that it is impossible for combustion to take place in any but the correct way. There is no danger of the gas or air leaking, or short-circuiting, and every part is easily accessible for cleaning without disturbing the brickwork. With this furnace temperatures of 1400 deg. Cent. (2550 deg. Fahr.) are quite easily obtained. The furnace is heated up at a remarkable speed; its floor is designed so as to give the construction a degree of strength much in excess of anything which has hitherto been found possible in gas furnaces.

GERMAN WAR PROFITS.

Whilst a number of German industries are suffering intensely from the war, so much so that Government interference has been considered necessary, others are earning huge profits. Thus the Ludw. Loewe Company (machine-tool makers, small arms, &c.) has beaten its previous war record, which then caused considerable surprise; the net surplus for 1915 amounts to 4,338,178 marks, against 2,905,684 marks for 1914, and the dividend (on 10,000,000 marks capital) has been fixed at 35 per cent., against 30 per cent. for 1914 (on 7,500,000 marks capital). The report states that last year has been one of most intense activity. The demand for machine tools, &c., has been constantly increasing, and also promises well for the current year. The army orders, however, show a falling off. As regards the concerns in which the Loewe Company is interested, the Company for Electrical Undertakings will probably pay 6 per cent., as for the preceding year; the Typograph Company is not likely to pay any dividend for 1915, whilst the Knorr Brake Company is doing satisfactorily. The Loewe Company has followed the example set by a good many other concerns by including the war-profit-tax reserve under "creditors," a method to which exception has several times been taken.

Also the German Arms and Munitions Factories, as might be expected, have done exceedingly well during last year, the surplus amounting to 12,487,781 marks, against 8,183,136 marks for 1914; a dividend of 30 per cent. (against 20 per cent. for the preceding year) has been proposed; 1,000,000 marks are reserved for war-aid purposes, and 1,000,000 marks for the company's pension funds, but no mention is made of war-profit-tax reserves.

The Krefeld Steel Works, which are closely connected with the important August Thyssen concern, have done exceedingly well during 1915, the working surplus amounting to 6,926,103 marks, against 1,926,448 marks in 1914. The writings-off on the works amount to 1,047,557 marks, in addition to 1,108,566 marks on special new war plant, &c., which has entailed an expenditure of 2,198,801 marks. A sum of 1,500,000 marks has been reserved for the war-profit tax. The net profits amount to 2,127,408 marks, against 672,346 marks during the previous year. The shareholders obtain a dividend of 15 per cent., against 12 per cent. for the previous year, a sum of 1,250,000 marks going to a special fund. The report does not make any mention of the army contracts of last year, which have yielded such substantial profits, but the past months of the present year have been satisfactory, as are the prospects for the future. The Krefeld Steel Works also made special quality steel prior to the war, more especially for machine tools, motor-car requirements, &c.

OPENINGS FOR BRITISH TRADE.—The Commercial Intelligence Branch of the Board of Trade has recently issued lists stating that a large number of firms in the United Kingdom wish to enter into communication with British manufacturers of machinery for making pins, hair-pins and safety-pins; machinery for making press buttons of all sizes; machinery for making paper and cardboard; machinery for making boot-lace braid; machinery for canning; and machinery for making asbestos roof-slates, cement tiles, tin boxes, wire of hexagonal section and machinery for making wood flour. If makers of the above will communicate with us, we will hand over their replies to the Commercial Intelligence Branch.

UNITED STATES STEEL CORPORATION.—The unexecuted orders of the United States Steel Corporation show a still larger aggregate, standing as they did at the close of March at 9,331,001 tons, as compared with 8,568,966 tons at the close of February, 7,922,767 tons at the close of January, 7,806,220 tons at the close of December, 7,189,489 tons at the close of November, 6,165,452 tons at the close of October, and 5,317,618 tons at the close of September. At the close of March, 1915, the corresponding total stood at 4,255,749 tons, so that the balance of unexecuted orders has more than doubled during the last twelve months. At the close of September, 1914, the unexecuted orders exhibited a still smaller aggregate, amounting as they did then to only 3,787,667 tons. There has thus been a great revival in the business of the Corporation since the first shock of the European war. In March, 1914, the unexecuted orders exhibited an aggregate of 4,277,068 tons, while at the close of March, 1913, the unfilled orders made up a total of 7,468 956 tons.

THE EFFICIENCIES OF TOOL STEELS.

*Note on the Relations between the Cutting Efficiencies of Tool Steels and their Brinell or Scleroscope Hardnesses.**

By J. O. ARNOLD, D.Met., F.R.S., Professor of Metallurgy in the University of Sheffield.

IN papers recently read before the Iron and Steel Institute there has been a tendency to regard the Brinell and scleroscope numbers registered by hardened steels as an approximate measurement of their cutting efficiencies in the lathe. Indeed it has been suggested that, instead of ascertaining the efficiency of high-speed steels directly in the lathe, the Brinell test might be substituted for the costly and prolonged proceeding of making systematic lathe tests. The purpose of this brief communication is to show that not only is there no relation between Brinell hardness and lathe efficiency, but also that a plain carbon turning tool with very high Brinell hardness may, on comparison with another tool of considerably lower Brinell hardness, register an efficiency of practically zero, whilst the tool of, say, 15 per cent. lower Brinell hardness may run perfectly for, say, eighteen minutes, and during the last five minutes of the test cut cleanly at a blood-red heat before breaking down.

The Brinell hardness of a properly hardened tool is an almost negligible factor of efficiency. The efficiency depends almost entirely on the thermal stability of the simple or compound hardenites in the hardened steel. The simple hardenite of plain carbon steel has a thermal stability of which the limit is certainly less than 300 deg. Cent., whilst the compound hardenite of a C-W-Cr-V high-speed steel, also secured by water quenching, may be rendered stable up to a temperature of about 700 deg. Cent. The proof of the foregoing enunciation is embodied in Table I.

TABLE I.

University Steel No.	Type of Steel. Compositions nearly Identical for each Type.	Duration of Tests in Minutes and Seconds before Breaking Down. 1st Grind.	2nd Grind.	3rd Grind.	Mean.	Efficiency. Cub'c Inches of Standard Hard Steel Shaft removed. 1st Grind.	2nd Grind.*	3rd Grind.	Mean.	Brinell Hardness No. Pressure, 3000 kilos.; Ball, 10 millimetres Diameter.	Scleroscope Hardness No. Average of Four Tests.
		m. s.	m. s.	m. s.	m. s.						
1523	Tungsten-chromium ..	10 7	11 45	9 26	10 26	47.4	56.3	43.3	49.0	600	82.8
1527	" " ..	11 25	12 35	10 32	11 32	54.7	61.4	49.4	55.2	629†	80.5
1533	" " ..	10 26	11 50	11 31	11 18	48.9	56.7	55.0	53.5	578	80.3
1522	Tungsten - chromium-vanadium	14 17	17 59	13 40	15 19‡	72.3	96.2	68.0	78.9	600	80.3
1524	" "	17 2	17 49	16 57	17 24‡	91.0	95.2	89.1	91.8	600	75.5
1528	" "	16 2	17 52	16 57	17 24‡	84.1	95.7	89.1	89.6	600	76.3
1534	" "	15 21	17 10	15 45	16 27‡	79.0	91.6	81.1	83.9	600	81.0

Note.—The Brinell and scleroscope hardness were taken as near as possible to the hardened cutting edges of the various tools.

* It will be seen that with both types of steel the maximum efficiency is obtained on the second grindings of all seven tools.

† Duplicate test 629.

‡ Throughout these tests the cutting edge of the tool was red-hot at the breakdown points, and indeed for about five minutes previous to breaking down.

If tested, *cæteris paribus*, with the steels in Table I., a hardened best crucible-cast plain carbon steel, containing about 1.25 per cent. combined carbon, would endure for perhaps two seconds. Therefore its endurance would be roughly 0.3 per cent. that of the W-Cr steels and about 0.2 per cent. that of the W-Cr-V steels. Nevertheless its Brinell hardness would be about 700 as against the 600 numeral registered by the high-speed steels. Again, according to the mean Brinell test (602) the W-Cr steels should average an efficiency of 0.3 per cent. greater than the constant numeral (600) of the W-Cr-V steels, yet the actual efficiency of the latter is 63 per cent. greater than that of the former. In a word, the Brinell and scleroscope tests, whilst valuable means of rapidly approximately determining the elasticity of structural steels, are valueless, or indeed worse than valueless, for estimating the varying thermal stabilities of the hardenites which mainly determine lathe efficiency.

The author and Professor A. A. Read, D.Met., have shown† that there are four single hardenites, *i.e.*, solid saturated solutions of carbides, namely, iron hardenite ($Fe_{21}Fe_3C$), vanadium hardenite ($Fe_7V_4C_3$), tungsten hardenite (Fe_6WC), and ferro-molybdenum hardenite ($Fe_{21}Fe_3Mo_2C$).‡ The double, triple, and possibly quadruple hardenites of high-speed steels yet remain to be discovered, but owing to a grant-in-aid of 200*l.* from Sir Robert Hadfield, the author and Professor A. A. Read, D.Met., of the University of Wales, are now proceeding with this complex research.

AN EXPERIMENTAL TANK REPRODUCING WAVE MOTION.§

By Colonel G. RUSSO, R.I.N., Member.

SIXTEEN years ago I had the honour of reading before this Institution‖ a paper on the rolling of ships amongst waves. At that time the result of my studies on the subject had led to the creation of the *navipendulum* and of a wave-motion machine, by which the problem of a ship rolling on waves was brought from the field of mathematical investigation into the field of experimental research. As is known, in the navipendular method, there is: (*a*) a mechanical apparatus which represents the sea, possessing those characteristic properties of the wave by which the rolling of the ship is effected; and (*b*) a specially contrived pendulum which represents the ship, possessing those characteristic properties of any given ship which are in play in her rolling motion both in still water and amongst waves. The pendulum and the machine, put in action one with the other, reproduce on a small scale the rolling motion of the given ship amongst a given uniform series of waves. Two years later, in 1902, my apparatus was brought before this Institution,* where I had the honour of showing the results of the first applications made at that time.

Subsequently, similar machines, or others based on the same principles, have been constructed. At the Froude Tank for experiments in naval architecture in Spezia very interesting research work has been accomplished by my colleague, Lieut.-Colonel N. Pecoraro, among which were experiments concerning Frahm anti-rolling tanks, which led, I understand, to conclusive results. Upon the suggestion of Professor Sir John H. Biles, Mr. A. Cannon, of Glasgow University, using a machine designed on the same principles, succeeded in giving us very valuable results of experimental work on the effect of internal free water upon the rolling of a ship amongst a regular series of waves. His most valuable paper was read at the summer meetings of the Institution of 1913 in Glasgow.† Another apparatus, not differing much from that in Spezia, is in possession of the Superior Naval School in Genoa.

The wave-motion instrument, however, is not the sea, and the navipendulum is not the ship. The production of artificial waves in experimental tanks has for long attracted the attention of experimenters. In 1889, at the experimental tank in Spezia, Colonel Rota employed a kind of paddle-wheel. At Messrs. Denny's experimental tank in Dumbarton waves were produced by a large board immersed in the water and worked with rockers by men. Lastly, I think something new, and certainly something most important, has been or is being done by Admiral D. W. Taylor at the experimental model tank in Washington, because it has been recently announced that there will be installed an apparatus for artificially making waves, and it is expected that this equipment will permit tests that will give valuable data regarding the action of ships in waves at sea.‡

And here I should like to recall a prefatory part of my paper of 1900. In experiments, I then said, concerning still-water oscillations of ships (as well as in those relating to the resistance to motion, or to the efficiency of propellers in connection with a given ship) a model and a tank are required, representing on a small scale the ship and the waters in which she oscillates. Were it possible to produce in the tank regular, continuous, and well-proportionated waves, such a method would enable us to solve the problem of the rolling on waves. Nothing, I added, denoted that something of this kind would not be attained in future; but at that time we were handicapped by unsurmounted difficulties.

To-day I can say that every difficulty has been removed, for there is already in action the first example of an experimental tank, in which a regular wave motion of a limited mass of water is produced, the length, height, and period of the wave being regulated as wished. Figs. 1, 2, and 3 relate to the limited mass of water which is in play in the tank, as will be shown farther on. Fig. 4, page 452, shows the whole apparatus. Figs. 5 and 6, reproduced from instantaneous photographs, show the machine in operation, with a model of a ship freely oscillating on waves. The principles underlying the form of the apparatus are of the utmost simplicity; but its constructive details had to be studied with the greatest care.

A machine of this type may be defined as a special tank, the walls of which are made to take a continually changing distorted shape by means of a mechanism external to the tank, and bearing up and guiding the sides and bottom of the tank, the whole system being so contrived that the liquid contained in the tank takes a regular motion exactly resembling that of sea-waves.

The tank may at will be a large or a small one, and the proportions of its length, height, and depth may also be fixed as desired; moreover, the mechanism affecting its walls and bottom may be arranged to lend themselves to variable arrangements, so that the regular waves produced in the liquid may, in their length from crest to crest, and in their height from crest to hollow, conform to predetermined dimensions.

An apparatus of this kind not only conduces to a direct demonstration of the nature and properties of the wave motion, but also furnishes means for ascertaining, by the use of models on a small scale and by application of the great principle of mechanical similitude, the behaviour of ships in a seaway before they are built, and of testing the more or less influence on the rolling of any ship of forms of hull, arrangement of weights, addition of bilge-keels, and the adoption of anti-rolling tanks, gyroscopic stabilitisers, or other similar appliances. If the tank is sufficiently long, recourse may be had on the same system to ascertain the reduction in speed and effects of pitching arising from the waves. Generally speaking, the system may be useful in experimental researches as to the effects produced by waves on any ship, freely floating and passively rolling, or otherwise steaming with a given speed across a system of regular waves.

The design of my tank is founded on the well-known principles that in the wave motion of the sea, supposed to be regular and without disturbing causes, only the undulated profile of the wave advances indefinitely in a direction perpendicular to that of the crests and hollows, whereas any mass of water has a circumscribed and well-defined motion. Taking into consideration the movements of the single particles of water, and supposing the depth of the sea to be unlimited, we know that each particle describes at a uniform rate a circular orbit contained in a vertical plane perpendicular to the direction of the crests, and makes a complete revolution in a time interval equal to the wave period. Likewise, if we take into consideration the motion of any portion of the mass of water, and we consider it distinctly from the whole mass of water of which it forms a part (in the same way as this same portion would be distinctly limited inside the fluid mass, were it alone to have a special distinctive colour), then the displacements and alterations of form, to which the limited mass of water is subject during the wave motion, are perfectly determined.

By the trochoidal theory, not only do we know that the considered mass of water comes on and on at the same point, and forms at every time interval equal to the period of the wave, but we are also able to specify exactly all the positions and forms assumed at each moment during a complete cycle of motion, namely, between two consecutive passages of the fluid mass in the same position and form.

To draw attention to a particular case having a special interest on the practical construction of the tank, let us consider, instead of a portion of the liquid mass, a portion like that represented by Fig. 1, where we see a prismatic shape in the direction of the crest of the wave and two base planes perpendicular to that direction. The mass of liquid, or the liquid body, in consideration is geometrically so limited that, were it deprived of the wave motion and reduced to rest, it would settle down into a regular shape with plane and parallel limiting surfaces at right angles.

The six surfaces limiting the mass of water represented in Fig. 1 may be precisely described as follows:—

(*a*) An upper free surface, A B C D, having a trochoidal undulation and continually oscillating about a certain middle horizontal plane, the *locus* of the centres of the circular orbits (all of the same diameter equal to the wave height) described by the liquid particles originally lying on the horizontal surface level.

(*b*) A bottom surface, E F G H (a trochoidal subsurface relative to A C B D), continually oscillating about a certain middle horizontal plane, the *locus* of the centres of the circular orbits, all of the same diameter, described by the liquid particles lying on the considered subsurface.

(*c*) Two plane surfaces, A D H E, B C G F, perpendicular to the direction of the wave crest, each of them containing a layer of liquid particles which describe their circular orbits always in the same plane, while continually changing their relative positions.

(*d*) Two distorted side surfaces, A B F E, D C G H, continually modifying their shape, and each of them continually oscillating about a vertical plane, the *locus* of the centres of the circular orbits, gradually decreasing in diameter with the depth, described by the liquid particles lying on the considered surface.

With the aim of rendering clearer how the structure of the wave must be conceived agreeably with the trochoidal theory, Fig. 1 shows not only the six surfaces limiting the considered mass of water, but also a certain number of subhorizontal and subvertical surfaces by which the liquid mass is subdivided in a certain number of liquid prisms parallel to the direction of the crest. These liquid prisms have their sections of a quadrilateral shape continually changing whilst the wave motion proceeds.

Fig. 2, page 451, represents the form assumed by the same mass of water shown in Fig. 1, after a period of time equal to half the period of the wave has passed, viz., at the moment when a crest has taken the place of a hollow, and *vice versa*.

Finally, Fig. 3, page 451, shows the shape of the same mass of water supposed to become deprived of its wavy motion and reduced to calm without stirring. As we had supposed *a priori*, the geometrical form now becomes

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* Paper read before the Iron and Steel Institute on Friday, May 5, 1916.

† *Proceedings of the Institution of Mechanical Engineers*, November, 1915, p. 645. Also ENGINEERING, Vol. c., page 555.

‡ This substance might be accurately classed as a sort of double hardenite.

§ Paper read before the Institution of Naval Architects, April 12, 1916.

‖ See Trans. I.N.A., Vol. xlii., page 30; ENGINEERING, Vol. lxix., pages 442, 454, 493.

* Trans. I.N.A., Vol. xliv., page 76; ENGINEERING, Vol. lxxiii., pages 402, 520, 590.

† See Trans. I.N.A., Vol. lv. (Part II.), page 76, ENGINEERING, Vol. xcv., page 882, and Vol. xcvi., page 102.

‡ See *The Engineer*, February 11, 1916, Vol. cxxi., page 130.

that of a parallel, and this is subdivided by equally spaced planes in a number of small prisms having a uniform square section.

Now it is clear that the principle stated before in a general way concerning any portion whatever, and of any shape, of the fluid mass of the wave, still applies to the mass of water which we have specially considered, as represented by Figs. 1 to 3; that is to say, the motions and changes of form of the five surfaces (sides, ends and bottom) separating the mass of water from the surrounding liquid are mathematically determined, as are also the motions and changes of form of the sixth surface, the free surface in contact with the air (A B C D in Figs. 1 to 3).

In the meantime there is the advantage, in respect to the general case, that in our particular one the geometrical and kinematical determination of shapes and motions is much easier than in the generality of cases.

Starting from the notion stated above, which has been drawn from the commonly accepted theory of trochoidal waves, I have thought that the sides, end and bottom surfaces, five in number, separating a certain

Fig. 1.

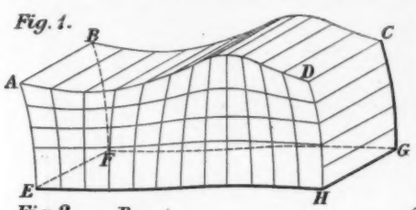


Fig. 2.

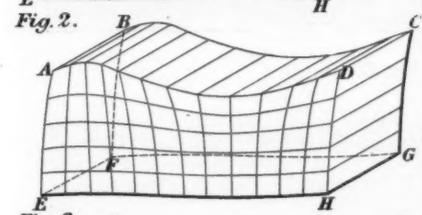
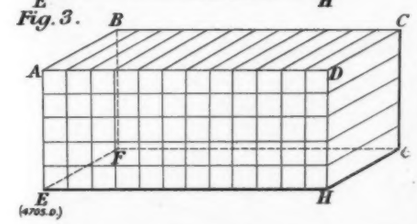


Fig. 3.



(4705.D.)

mass of water from the surrounding liquid mass, may be imagined to be materialised in five thin sheets of some elastic substance, so that these transforming sheets may follow all the motions and changes of form of the imaginary separating surfaces inside the water. Supposing this, it follows that the liquid enclosed within the five elastic walls would continue identically to follow its regular motion as before, though now materially separated from the surrounding water.

Let us make a forward step, and suppose: (*a*) That the five elastic sheets are joined together one with the other, so as to result in an elastic transforming vessel or tank, and (*b*) that the water outside the tank is taken away, while the same tank, supported and duly guided by some outward mechanism, is forced identically to continue in the same motion as when it was supported and guided by the surrounding water. In such conditions what may we expect to happen? It is clear that the liquid contained in the tank will continue in its regular wavy motion as before, viz., as when it was a part of the actual wave. In effect, referring to Figs. 1 to 3, it makes no difference whether A D H E, B C G F, A B F E, D C G H, E F G H are five imaginary surfaces in the moving liquid, or the boundary of a material elastic vessel. In conclusion, following the explained method, we are able to separate from the mass of the waves a definite portion without altering in any way its dynamical conditions; that is to say, preserving in it the wave motion, unchanged in its original length, height, and period.

The actual apparatus has proved fully in accordance with the principles upon which it was devised, having given all that was expected from it. When the apparatus is in action, the water finds within the walls of the tank its regular settlement of a uniform wave motion, just in the same way as the same water would settle smoothly at a horizontal level inside a tank at rest.

On my part, I must avow that while the apparatus was in construction I was in no perplexity at all as to the practical result coinciding with the theory. Certainly the question had yet to be confirmed by experiment; but I did not believe that the water in the tank could have any reason or any power to refuse obedience to the same laws as it would have been obliged to follow if surrounded by other water. I think it possible that actual sea waves follow unknown laws, not agreeing fully with the theory of trochoidal waves; but I also think that this theory is so perfect in itself from the geometrical and mechanical point of view as to leave no doubt whatever about the possibility of creating a regular wave motion based on this theory. Of this latter conclusion my apparatus gives confirmatory evidence (I dare say the only possible experimental evidence), if a confirmation may be considered necessary.

It is not necessary to describe constructional details of the apparatus here. I wish only to say that the present small tank, the only one now existing, has the following internal dimensions:—1.20 by 1.00 m. (47.24 by 39.37 in.), with depth of water of 0.50 m. (19.68 in.); waves may be produced in length from 0.40 m. (15.75 in.) up to 3.60 m. (11 ft. 10 in.), and in height from zero up to 90 mm. (3.54 in.).

Figs. 5 and 6 (page 452) are reproduced from instantaneous photographs taken while the waves in the tank had the length of 1.80 m. (5 ft. 11 in.) and the height of 60 mm. (2.36 in.), the proportion of height to length being 1.30. From these photographs it is clearly perceptible that the wave profile follows exactly the line of the buttons supporting the wall of the tank, which buttons in their turn, by the construction of the machine, are always following a trochoidal line.

The tank itself is made of india-rubber. The number and disposition of the points through which the tank is supported and forced to follow the law of motion of the trochoidal theory correspond to the representation given in Figs. 1 to 3. Thus the front wall of the tank is carried about and guided by 78 button pins (six rows of 13 button pins), the centres of which are equally spaced, the distance being 10 centimetres between the successive rows both in the vertical and in the horizontal direction; the opposite wall B C G F has an equal number and distribution of button pins; the bottom E F G H, as well as the end walls A B F E, D C G H, are carried about and guided by 23 solid bars connected to the button pins of the lower horizontal row and of the vertical end rows.

It will be understood that each of the 156 button pins is connected with a mechanism by which it is obliged to take an orbital rotation about a corresponding fixed axis. It is for this reason that we have made reference to the *middle positions* of the button pins, but in reality only the 156 fixed axes are equally spaced and regularly distributed, as in Fig. 3.

It will also be understood that each of the mechanisms carrying a button pin is alterable at will, so that it may be suitably arranged to obtain: (*a*) The *eccentricity*, namely, the distance from the fixed axis to the corresponding pivoting pin, or the radius of the circumference to be described by the pivoting pin. (*b*) The *angle of procession*, namely, the angle with respect to a position zero, in which the radius of eccentricity of all the button pins would result in an exactly parallel direction.

Of course, such a small tank as that which is the object of the present paper lends itself rather to demonstrations than to correct comparisons between models and full-sized ships. In fact, having regard to the size of the models which may be put to float in the tank (20 in. to 25 in. in length), the scale of reduction of linear dimensions results in about 1/200th to 1/400th of the full scale.

But nothing prevents us from constructing tanks large enough for correct experiments. Moreover, it is well to add that a considerable simplification may be introduced in the design, on the ground of the well-known fact that a wave advancing in a canal sufficiently deep suffers no sensible alteration in its regularity nor in its geometrical and mechanical characteristics, notwithstanding a small amount of friction of the water against the side walls. Therefore we are justified in such case in using the system of elastic mechanically operated walls only at the ends of the tank, and eliminating any arrangement of this kind for the side walls. Then, except for the ends, the tank (sides and bottom) might be built in masonry. Of course, the motions of the elastic end walls must be in due correlation, one with the other, by some mechanical transmission established between them. One of these could be conceived as a generator and the other as an absorber of waves; but, in fact, once the regularity of motion is established, there is neither a creation nor an absorption of motion, nor is there any other energy wasted than that for passive resistances only.

I believe a tank 8 to 10 metres wide and 15 to 20 metres long would be sufficient for employing in rolling experiments amongst waves the same models used for ship resistance experiments.

The design of the small experimental tank, which is the subject of the present paper, was submitted by me to His Excellency Admiral E. Millo, then Minister of Marine of Italy, in March, 1914, when the construction was entrusted to the *Stabilimento Elettromeccanico* of Messrs. Ansaldo, in Cornigliano, Ligure. Slow was its progress on account of more urgent works depending on war exigencies. The construction was achieved, and the first trial in it took place on February 24 of this year. As aforesaid, the result was very satisfactory.

In conclusion, it is my duty to express my very great indebtedness to H.E. Admiral Millo for having given his approval to my proposition and ordered the construction of the apparatus. My best thanks are also due to the principals of the firm Ansaldo and Co., of Genoa, and particularly to Mr. V. Locarni, the director of their works in Cornigliano, Ligure, for their goodwill and best efforts in this matter.

NOTE ON ECHELON WAVES.

By Sir GEORGE GREENHILL.

These waves have been described and illustrated by W. Froude (Transactions I.N.A., 1877), and an explanation was given by Sir William Thomson (Proc. Institution of Mechanical Engineers, 1887), reprinted in his "Popular Lectures;" also by R. E. Froude, on "Ship Resistance" (Greenock Philosophical Society, 1894), and Hovgaard (Trans. I.N.A., 1909). They are seen stretching aft from the bow wave in a line of echelon, and can be watched at sea on a calm day from the deck of a steamer till they disappear over the horizon. On a small scale the wake of a duck will exhibit the waves quite clearly. The effect is explained by a combination of interference and group velocity; and the following geometrical construction is submitted to replace a long analytical calculation.

The bow wave is thrown off in a hump at O in the figure, with the crest O E at an angle θ with the beam, and it is followed by the next wave B C, thrown off at B on the side O B of the ship. Looking along B C, a hump is seen at C on the wave, and this is followed by a series of equidistant humps on the line O C, showing a series of waves, following the ship in echelon, with the crest parallel to the bow wave at O; the problem is to calculate the angle ϕ which O C makes with the beam. The perpendicular O A on B C is the wave length, λ, between the parallel crests O E, B C; and representing the speed of the ship, K knots, by the vector O K, and drawing K V perpendicular to A O produced, then O V is the vector representing the wave velocity, V knots.

The hump at C is produced by the interference of the wave A′ C, of slightly different length O A′, $\lambda + d\lambda$, and velocity O V′, V + d V, at a small angle A O A′; and then in the figure:

$$\frac{VK}{AC} = \frac{V}{Aa} = \frac{dV}{d\lambda}$$

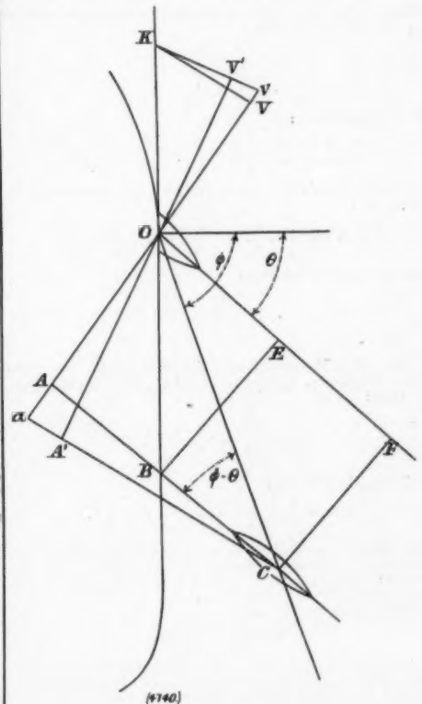
$$\frac{AB}{VK} = \frac{OA}{OV} = \frac{\lambda}{V}$$

and drawing C F perpendicular to O E:

$$\frac{AB}{AC} = \frac{OE}{OF} = \frac{\lambda\, dV}{V\, d\lambda}$$

$$\frac{BC}{OF} = 1 = \frac{\lambda\, dV}{V\, d\lambda} = \frac{G}{V}$$

where G denotes the group velocity of the waves.



(4740)

When V is assumed to vary as some power, q, of λ, so that:

$$\frac{dV}{d\lambda} = q\,\frac{V}{\lambda}$$

or, in the popular language of the practical man, 1 per cent. increase in λ gives q per cent. increase to V, then:

$$G = (1 - q)\,V,$$

$$\frac{AB}{AC} = \frac{AB}{AO}\,\frac{AO}{AC} = \tan\theta \tan(\phi - \theta) = \frac{\lambda\, dV}{V\, d\lambda} = q.$$

Thus, in deep-water waves, where the velocity varies as the square root of the length:

$$V = \sqrt{\frac{g\lambda}{2\pi}},\ q = \frac{1}{2},\ G = \frac{1}{2}V,\ BC = \frac{1}{2}.OF = OE.$$

In short capillary waves, produced by drawing the point of a stick through water, $q = -\frac{1}{2}$, and no echelon waves are discernible.

In air the sound-waves are propagated with the same velocity for all wave lengths, otherwise music would be impossible and could not exist. Then $q = 0$, $\phi = \theta$, and the echelon waves are merged in the wave front. This is shown in the bullet photograph, where the bow and stern waves are very clear and distinct in the air. With the very sharp point of the new bullet, the head is seen penetrating the bow wave, as in the sharp bow of a steamer.

Group velocity of sea-waves was known to the sailor

of all time, in his proverbial formula of every tenth wave a big one. Ovid records it on his voyage into exile:

"Qui venit hic fluctus, fluctus supereminet omnes
Posterior nono est, undecimoque prior."
"Vastius insurgens decimæ ruit impetus undæ."

The theoretical explanation appears to be given first by Stokes. He considers the interference of two wave-trains, moving in the same direction with wave-length and velocity nearly equal. The effect is to make the amplitude of rise and fall at one spot to diminish and then increase again in a period larger than the oscillation. This is observed when we follow with the eye the crest of a particular wave of the sea. After a maximum height it is seen to die down gradually, and meanwhile a bigger wave has been growing up behind. A simple pure wave of elevation given by:

$$y = a \sin \frac{2\pi}{\lambda}(x - V t)$$

is replaced, in Stokes's explanation, by two such waves, nearly equal:

$$y_1 = a_1 \sin \frac{2\pi}{\lambda_1}(x - V_1 t), \quad y_2 = a_2 \sin \frac{2\pi}{\lambda_2}(x - V_2 t)$$

and their resultant, at the same time, t, and same place, x, is given by:

$$y_1 + y_2 = \frac{1}{2}(a_1 \pm a_2)\left[\sin \frac{2\pi}{\lambda_1}(x - V_1 t) \pm \sin \frac{2\pi}{\lambda_2}(x - V_2 t),\right]$$

$$= (a_1 \pm a_2) \begin{matrix}\cos \\ \sin\end{matrix} \pi \left[\frac{x}{\lambda_1} - \frac{x}{\lambda_2} - \left(\frac{V_1}{\lambda_1} - \frac{V_2}{\lambda_2}\right) t\right]$$

$$\begin{matrix}\sin \\ \cos\end{matrix} \pi \left[\frac{x}{\lambda_1} + \frac{x}{\lambda_2} - \left(\frac{V_1}{\lambda_1} + \frac{V_2}{\lambda_2}\right) t\right]$$

representing two waves, of length and harmonic mean of λ_1 and λ_2, and velocity:

$$\frac{\frac{V_1}{\lambda_1} + \frac{V_2}{\lambda_2}}{\frac{1}{\lambda_1} + \frac{1}{\lambda_2}}$$

but of amplitude:

$$\begin{matrix}(a_1 + a_2) \cos \\ (a_1 - a_2) \sin\end{matrix} \pi \left[\frac{x}{\lambda_1} - \frac{x}{\lambda_2} - \left(\frac{V_1}{\lambda_1} - \frac{V_2}{\lambda_2}\right) t\right]$$

equivalent to a wave of long period T and great length L, given by:

$$\frac{2\pi}{T} = \pi \left(\frac{V_1}{\lambda_1} - \frac{V_2}{\lambda_2}\right), \quad \frac{2\pi}{L} = \pi \left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right)$$

advancing with velocity:

$$G = \frac{\frac{V_1}{\lambda_1} - \frac{V_2}{\lambda_2}}{\frac{1}{\lambda_1} - \frac{1}{\lambda_2}}$$

This G is the group velocity given above, when the wave length, λ_1, λ_2, and velocity, V_1, V_2, is nearly equal, so that:

$$G = \frac{d\frac{V}{\lambda}}{d\frac{1}{\lambda}} = V - \frac{\lambda\, d\, V}{d\, \lambda}.$$

In capillary waves:

$$q = -\frac{1}{2}, \quad \frac{\lambda\, d\, V}{d\, \lambda} = -\frac{1}{2}V, \quad G = \frac{3}{2}V,$$

and this group velocity can be observed, it is said, in the diverging circles made when a small stone is thrown into water; dark streaks of reflection are seen passing over the waves with double velocity.

In deep-water waves,

$$q = \frac{1}{2}, \quad G = \frac{1}{2}V,$$

The sea-waves are not pure waves, but are in a state of perpetual mixture and interference. But the echelon waves are sifted out, and persist unchanged as pure permanent waves, as far as they can be seen on a calm day. Homer, too, has recorded a simile of the waves on a corn-field as well as the sea (Iliad II., 144–149), quoted by Scott Russell in his report on "Waves," to the British Association, 1844, and imitated by Shelley in "the ripe corn under the undulating air undulates like an ocean." But here each cornstalk vibrates or undulates independently in the same period, so that V varies as λ, $q = 1$, and $G = 0$; and the appearance is explained of the stationary patches in the waves of the corn-field in a wind, compared by Homer to the stage crowd of the public assembly in the market place.

Regenerating Sulphated Accumulator Electrodes.—In the course of a research on lead sulphate and lead, G. A. Perley and C. W. Davis, of Durham College, New Hampshire (*Journal of Physical Chemistry*, February, 1916), observed that sulphated electrodes of secondary batteries could be regenerated by being placed in caustic soda, without the use of an external current. The method, however, was not satisfactory, and after trying various solutions—sodium sulphate, chlorate, phosphate, carbonate, tartrate, &c., with or without the addition of caustic soda—they found that the old method of regeneration by sulphate of sodium was, after all, the best. They advise the placing of two additional positives next to the two outer negatives, in order to hasten the regeneration of these latter electrodes. The regeneration is effected by supplying the ordinary charging current for about 60 hours.

AN EXPERIMENTAL TANK FOR REPRODUCING WAVE MOTION.

(*For Description, see Page* 450.)

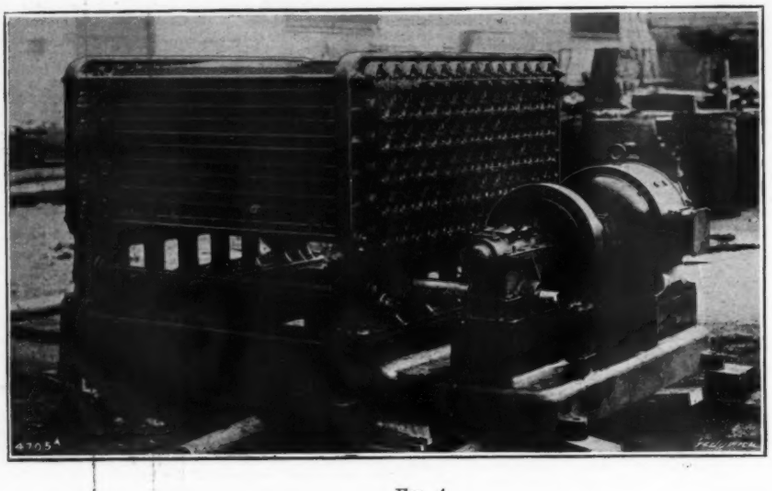


Fig. 4.

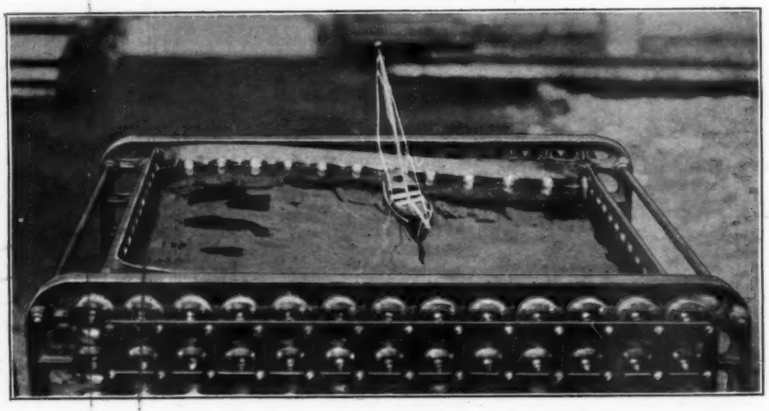


Fig. 5.

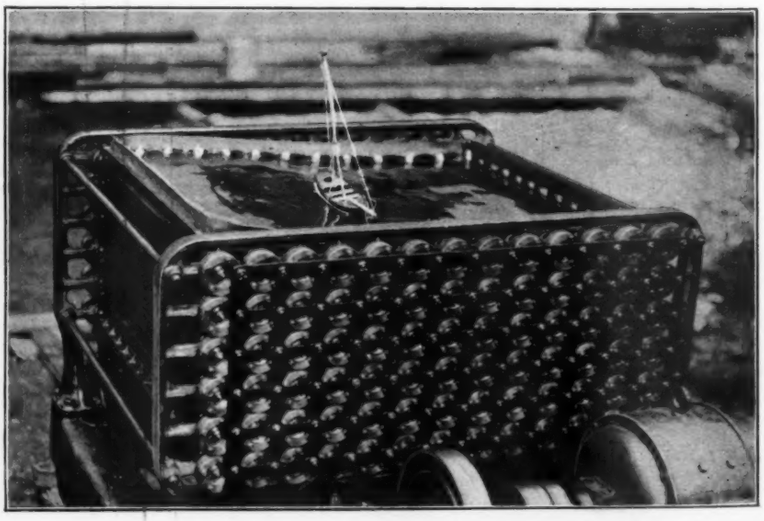


Fig. 6.

The Electric Industry in Sweden.—The General Swedish Electrical Company in Värteras, Sweden, after the usual writings off, has earned net profits amounting to 4,600,000 kr. (255,000*l.*) for last year, against 2,197,373 kr. for the preceding year. The shareholders obtain a dividend of 12 per cent., against 9 per cent. for 1914; 1,000,000 kr. are added to the fund at disposal and 420,000 kr. to the dividend equalisation fund.

GRINDING MACHINES.

(*For Description, see Page* 443.)

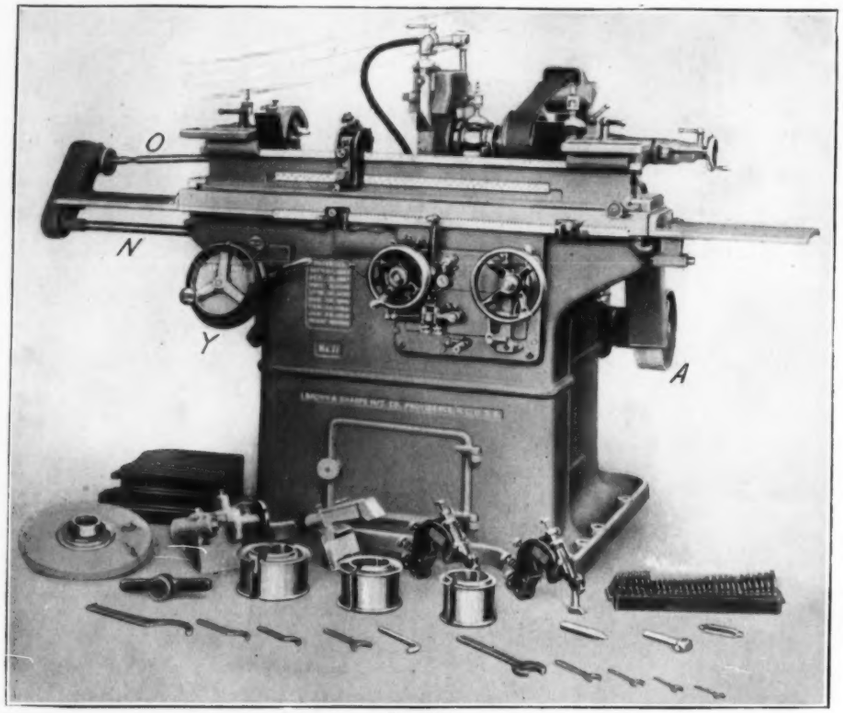


FIG. 361.

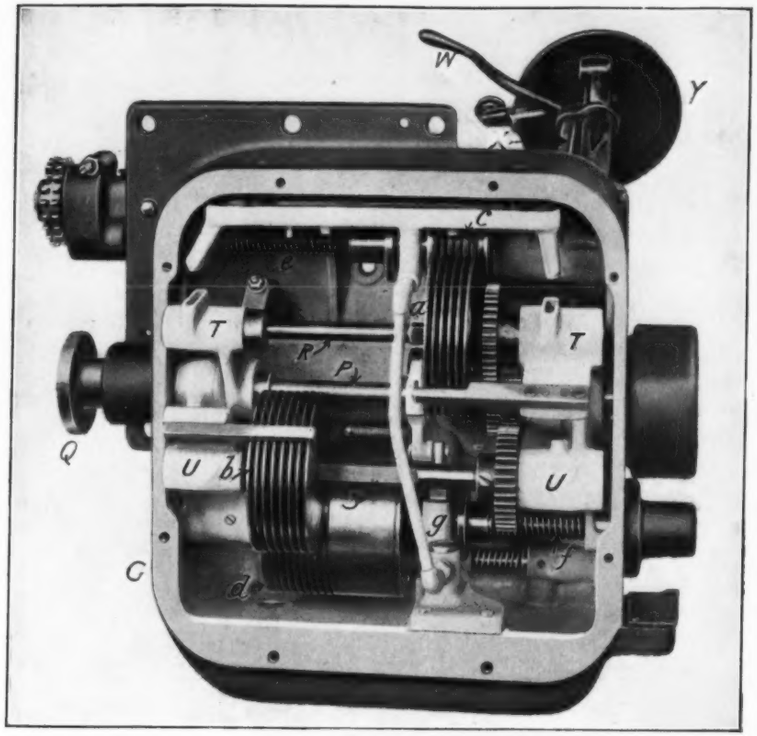


FIG. 364.

Fig. 362.

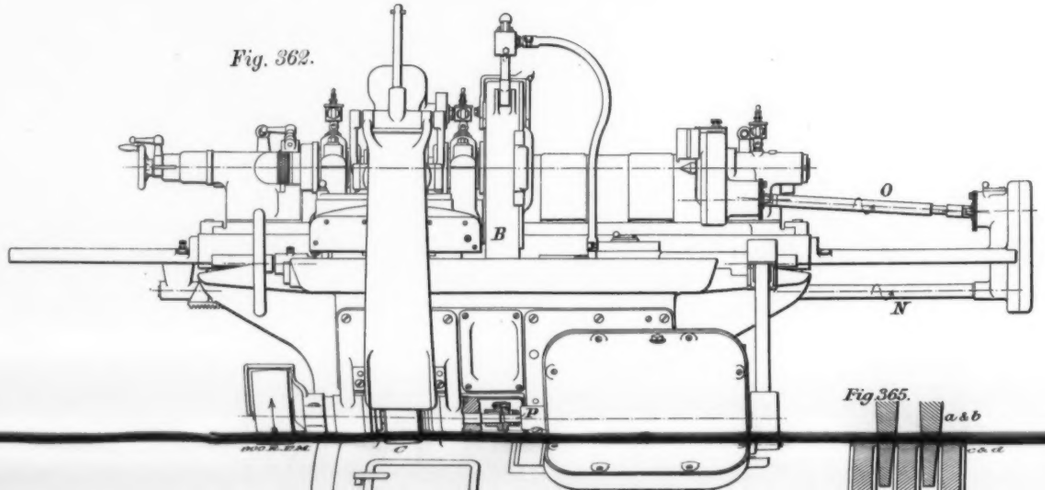
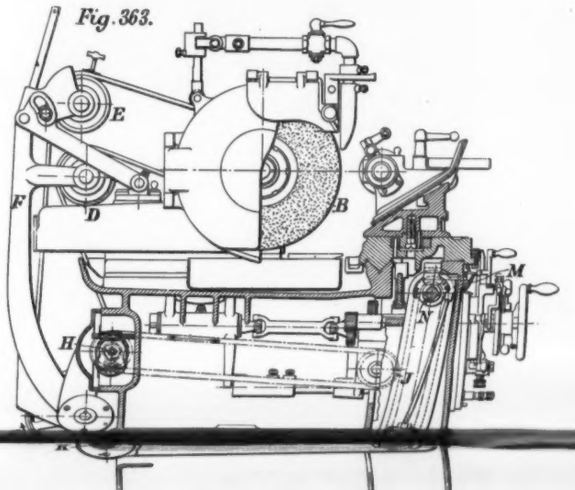
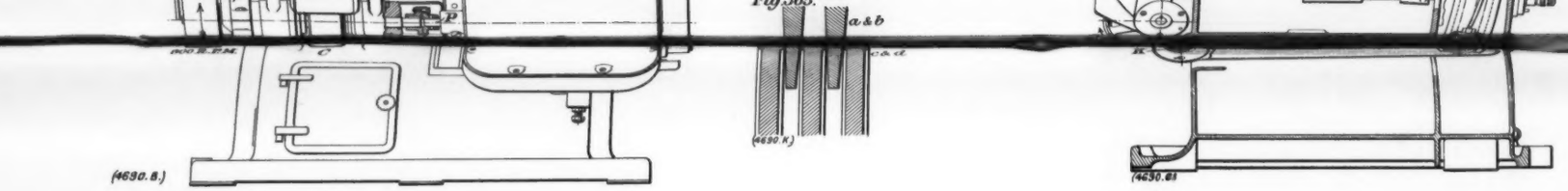
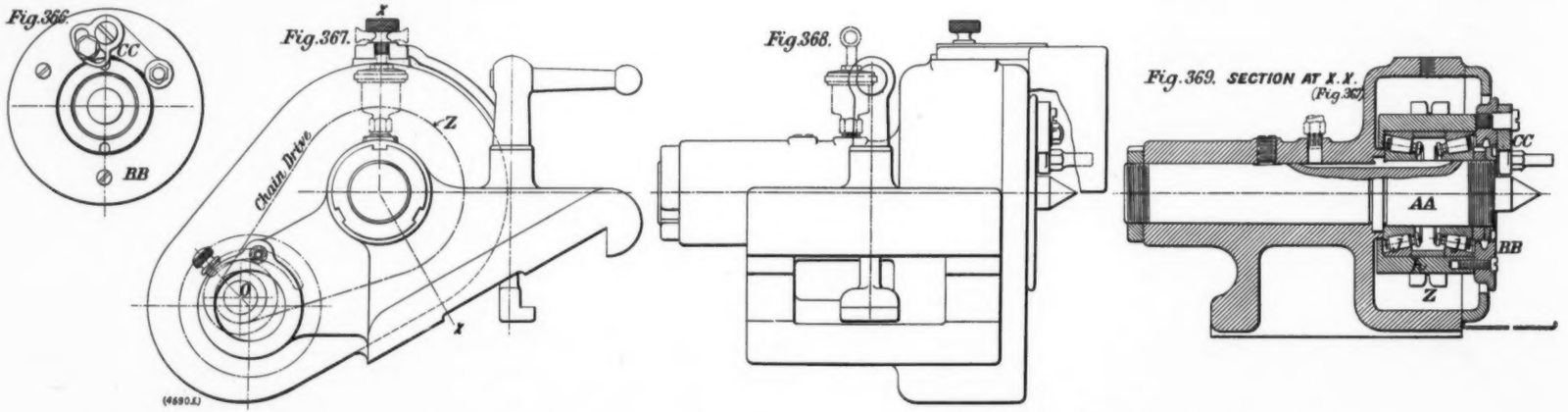


Fig. 365.

Fig. 363.







FIGS. 361 TO 369. GRINDING MACHINE WITH SINGLE-PULLEY DRIVE; THE BROWN AND SHARPE MANUFACTURING COMPANY, PROVIDENCE, RHODE ISLAND.

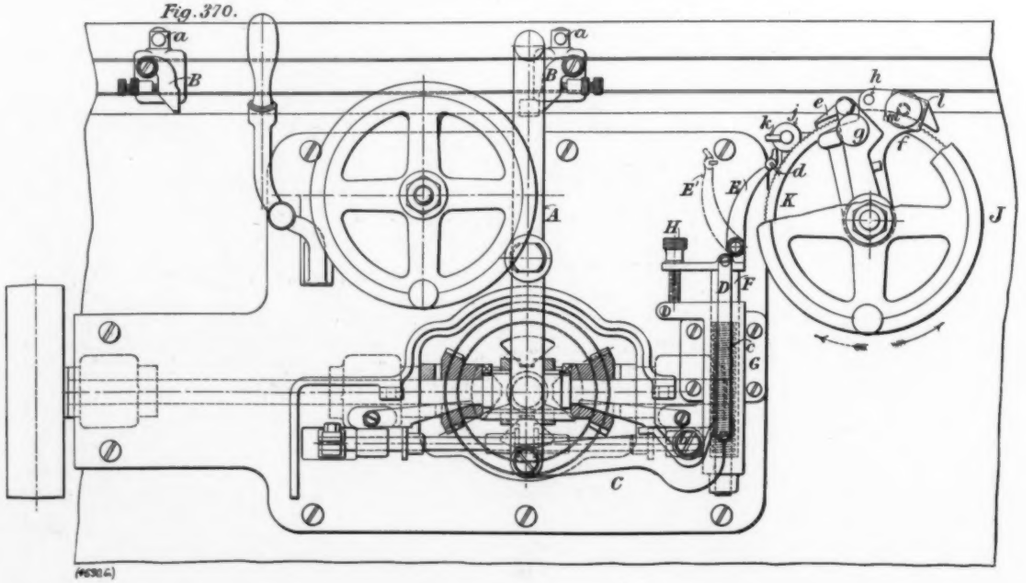


FIG. 370. AUTOMATIC CROSS-FEED OF WHEEL-HEAD OF GRINDING MACHINE, BY THE CINCINNATI GRINDER COMPANY, OHIO, U.S.A.

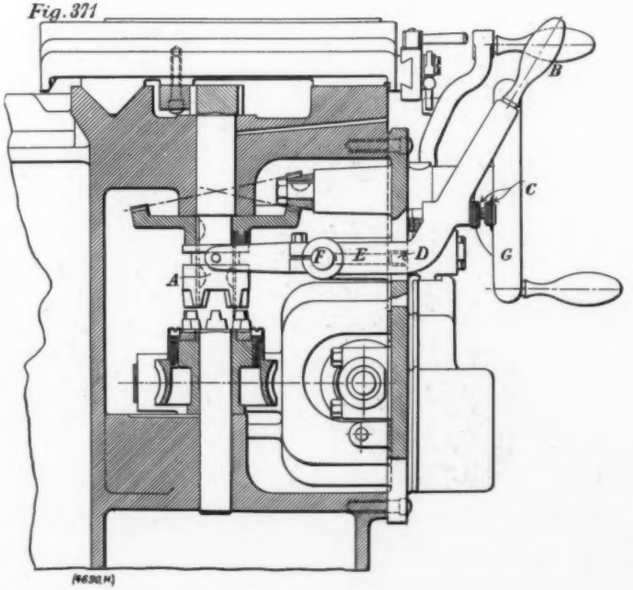


FIG. 371. GEAR FOR PRODUCING "DWELL" AT THE END OF TABLE STROKE; THE CINCINNATI GRINDER COMPANY, OHIO, U.S.A.

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The charge for advertisements is three shillings for the first four lines or under, and eightpence for each additional line. The line averages seven words. Payment must accompany all orders for single advertisements, otherwise their insertion cannot be guaranteed. Terms for displayed advertisements on the wrapper and on the inside pages may be obtained on application. The pages are 12 in. deep and 9 in. wide, divisible into four columns of 2¼ in. in width. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

Advertisements intended for insertion in the current week's issue must be delivered not later than 5 p.m. on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than 1 p.m. on Tuesday in each week.

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With a Two-Page Plate of GRINDING-MACHINES.

NOTICES OF MEETINGS.

THE ROYAL SOCIETY OF ARTS.—Monday, May 15, at 4.30 p.m. Cantor lecture: "Vibrations, Waves, and Resonance," by Mr. J. Erskine-Murray, D.Sc., F.R.S.E., M.I.E.E. (Lecture III.). Wednesday, May 17, at 4.30 p.m. Ordinary meeting: "Hindu Hand-Painted Calicoes of the Seventeenth and Eighteenth Centuries, and their Influence on the Tinctorial Arts of Europe," by Mr. George Percival Baker. Sir William Martin Conway, M.A., F.S.A., F.R.G.S., will preside.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.—Tuesday, May 16, at 8 p.m., at the House of the Royal Society of Arts, John-street, Adelphi, W.C. The following paper will be read: "Petroleum Refining," by Mr. Andrew Campbell. The chair will be taken by the President, Professor John Cadman, C.M.G., D.Sc., M. Inst. C.E.

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, May 19, at 6 p.m., at the Institution of Civil Engineers, Great George-street, Westminster. Subject of paper: "Spur-Gearing," by Mr. Daniel Adamson, Member.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Friday, May 19, at 5.30 p.m. A discourse will be delivered by Colonel E. H. Hills, C.M.G., R.E., D.Sc., F.R.S. The subject is "The Movements of the Earth's Pole." Afternoon lectures next week at 3 o'clock. Tuesday, May 16. Professor Charles S. Sherrington, M.D., LL.D., F.R.S., Fullerian Professor of Physiology, Royal Institution, on "Unconscious Nerves—their Functions in Internal Life." (Lecture I.). Thursday, May 18. Sir Ray Lankester, K.C.B., LL.D., D.Sc., F.R.S., on "Flint and Flint Implements" (Lecture III.). Saturday, May 20. Professor H. S. Foxwell, M.A., F.B.A., Fellow and Director of Economic Studies, St. John's College, Cambridge, on "The Finance of the Great War—New Problems and New Solutions" (Lecture I.).

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper, and of the consequent shortage of supplies, readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk. Owing to the scarcity of paper it will be impossible in future fully to provide for a chance demand for this Journal.

ENGINEERING.

FRIDAY, MAY 12, 1916.

THE POSITION OF THE BRITISH MERCHANT FLEET.

THERE is need for definite action to maintain the oversea carrying capacity of the British merchant fleet, in order to conserve our commercial and financial equilibrium now and after the war. At the same time, it is in the highest degree important that the subject should be viewed continuously in true prospective, and with calmness. German war tactics are largely influenced by the hope that they will be able to frighten us, or one or other of our Allies, into a premature peace on their terms. Any indication of unsettlement in public opinion, any suggestion of success, will induce our enemy to increase, as far as is possible, their ruthlessness with the desire to accelerate this mental or moral disturbance, and thus, while deprecating any concealment, especially of real or potential dangers, we contend for an intelligent and calm reading of the facts, so as to prevent unjustified alarmist deductions. Fortunately, amidst a recrudescence of fears regarding shipping losses, there has been issued the annual report by Lloyd's Registry of Shipping, showing the vessels added from all sources to, and removed by all causes from, the British merchant fleet during 1915 and preceding years, and this statement is of a reassuring character.

Lloyd's show that during last year, when Germany was doing her best to destroy our merchant fleet, and when an immense amount of work was being done in shipbuilding yards for the Navy at the expense of mercantile shipbuilding, the decrease in the tonnage of our commercial fleet was only 11,151 tons. But in its carrying capacity there was really an increase. It is computed that on an average a steamer does three times the work of a sailing ship. The steam tonnage showed an actual increase of 9137 tons, while the sailing tonnage was less by 20,288 tons. Thus, on balancing cargo-carrying efficiency, there was an increase. So far this is satisfactory under the circumstances, even although the annual increment in our steamship tonnage for the preceding nine years averaged 467,800 tons. There is, however, a steady disappearance of sailing ships, so that the net average addition has been for nine years 366,100 tons per annum, against the decrease for last year of 11,151 tons. Our fleet to-day aggregates 19,998,668 tons, the measurement of 20,797 vessels. If to this we add the 1,732,700 tons owned by the colonies, the Imperial commercial fleet equals 21,731,368 tons. The merchant marine of all other nations combined is only about two million tons greater, so that it will be a long time before our supremacy in this respect is affected.

The question arises as to what is now to be the rate of change in the relative positions of the maritime fleets. Are they building faster than we? Are their losses less? The immense profits being made by the shipowners of neutral countries—since the war began Holland, Denmark, Norway and Sweden are said to have netted eighty millions sterling—will enable those countries to build as fast as possible, irrespective of cost; but last year these four countries only produced 240,000 tons, and although the inducements to shipbuilders now are greater, there is increased difficulty in getting the material. On the other hand, Britain added 778,321 tons of new vessels to her fleet. Put in another way, the output of the four countries which are doing best in profits is about one-seventh of the average annual output of British yards in normal times. It would thus be possible within a year or two after the war to rectify the change in the relative positions. Again, as to losses by war, Germany, being no respecter of nations or their respective flags, has played pretty severe havoc with the ships of the four nations named. Lloyd's separate returns of ship losses show generally that the rate of loss per cent. of tonnage of the four countries named is as great as that for Britain, and they have not had such compensation in the capture of ships as fell to our lot before the German merchant flag was driven off the seas. These four countries, during the three months compassed by Lloyd's latest quarterly return, lost by war a total of 63,439 tons, which is at the same rate as their output in the corresponding months. There is thus little need to fear that we shall forfeit our place as the result of Germany's destructive action or any neutrals' increased productive work.

Our merchant fleet, so far as cargo-carrying capacity is concerned, has so far held its own, although the normal average rate of increase—something less than 2 per cent. per annum—has not been maintained. Our removals in 1915 totalled 741 steamers, of 1,452,679 tons, and 334 sailing ships, of 82,222 tons. The aggregate of 1,534,901 tons includes the loss by war and natural causes—which made up 1,105,597 tons; sales to foreigners, which accounted for 232,949 tons, mostly old steamers and principally to the United States, Norway and Greece; a few transfers to the Colonies, and other deductions, including four vessels captured by the enemy. But against these removals we have a fair showing. The enemy vessels "requisitioned," or taken over as prizes, total 194 and make up 557,879 tons, so that by this means we have made up a good proportion of the British merchant ship war losses. There were bought from foreigners 108,490 tons, almost entirely made up of steamers. The new vessels built included 377 steamers, of 769,530 tons, and 61 sailing vessels, of 8791 tons; and of the total of 778,321 tons, six vessels, of 10,672 tons, were built abroad. Thus the addition from various causes made up a total of 1,523,750 tons, while the deductions totalled 1,534,901 tons, leaving a deficit of 11,151 tons in the volume of the fleet.

As our fleet is still within a few tons of twenty millions, there is little need to be anxious about the menace of submarines, torpedoes and mines. Even our restricted resources just now for the building of merchantmen, owing to naval demands, are sufficient to make good current war loss. But there is the great difficulty in maintaining our sea-borne commercial trade, because the war requires the exclusive service of so much of our merchant tonnage. Over 43 per cent. of our tonnage has been requisitioned by the Government for the naval and military needs of the Allied countries, 14 per cent. has been engaged in carrying foodstuffs and raw material for the Allied armies' needs, leaving only 43 per cent. for commercial use, and even this is under State regulation. The shortage of shipping is explained, not so much by submarine activity, as by these facts, in association with the restriction of shipbuilding operations. Imports of great bulk and of more or less dispensable nature have been stopped; this has cut off from two to three million tons of imported goods. More might be done in this way. Again, in the State regulation of tonnage greater care might be exercised to obviate ships traversing the ocean in

ballast or being held up for any length of time in ports. Both remedies, and others for the more efficient use of shipping, are making progress as the result of experience; but the chief source of relief must come from the shipbuilding yards. The demands of the Navy are paramount, but there is hope that soon a greater proportion of merchant work will be proceeded with as essential to the prosecution of the war. The difficulty is that shipyard work is not conducive to dilution of labour by women workers, while the machinery constructors are needed for munitions and warship turbines. There is, however, more being done on merchant shipbuilding, and this course must be commended. We hope, too, for still more regular work by shipyard workers. The financial problem, due to the advance in cost of material and wages since contracts were made, is quite another and a very serious question. But, however this latter may be arranged, the Government must permit and encourage the building and completion of as many merchant vessels as can be accomplished consistent with the main duty of ensuring a speedy and victorious end of the war.

SOLID SOLUTIONS, ANNEALING AND PROPERTIES OF METALS.

THE fact that almost all the alloys, which owe their practical utility, thanks to their toughness or combination of strength and ductility, consist of one or more solid solutions, has received due attention, but has not yet found any adequate explanation. The brasses, most of the bronzes, copper-zinc-nickel alloys — formerly known as German silvers, now designated nickel-silvers— light aluminium alloys for motor vehicles, our coins, &c., are regarded as solid solutions, and the hardening of steel is attributed to the formation and subsequent preservation of solid solutions, to which again the predominating characteristics of alloy steels are ascribed. One might expect pure gold to be harder than gold containing another metal in solution, or, in a certain sense, as impurity, just as pure gold or any pure substance has a higher melting point than the impure substance. But it has long been understood that these two phenomena are not parallel. To what circumstance solid solutions of metals owe their special properties, in particular their high hardness, is not understood, however. The problems came before the Faraday Society at their meeting of Tuesday last. This meeting was not one of the discussions in which the Society excels, dealing with a definite range of problems; in fact, the titles of the papers on the list appeared of a mixed character. Yet all the papers dealt with really concerned cognate questions.

The particular papers which we wish to notice to-day in the first instance were by Mr. F. C. Thompson, M.Met., B.Sc., of Sheffield University, on "The Properties of Solid Solutions of Metals and of Inter-Metallic Compounds," and on the "Annealing of Metals." Mr. Thompson had made an important communication to the Iron and Steel Institute that afternoon, and had already brought a very suggestive investigation of the elastic strength of metals before the Faraday Society a few years ago. On Tuesday he first pointed out that great hardness of alloys went together with high electric resistance and with high maximum stress and low elongation, and that these properties were also conferred on the metals or alloys by cold work. The remarkable parallelism between the properties of a metal in the *écroui* condition and in solid solution with another metal suggested that distortion of the crystalline matter was present in both cases. Metallic solutions were truly crystalline; cleavage slipping under stress, well-defined etching pits and twinning pointed to that conclusion. In the space-lattice of such a solution the lattices of the two or more constituents were generally regarded as interpenetrating. Mr. Thompson, however, thought that the question might be simplified by considering one lattice alone. When an element B was added to an element A, the A atoms in the space-lattice were progressively replaced by the isormorphous B atoms, and the lattice passed imperceptibly from that of one pure element to that of the other. This atomic replacement should react on the physical properties, and implied, according to Gossner, an attempt at the equalisation of the atomic volumes in the components, in the sense that, if an A atom occupied a greater volume than a B atom, the replacement would result in an expansion of B and a contraction of A when they crystallised together. The resulting distortion would give rise to elastic strains, probably of a high order, throughout the whole mass, to which the increased hardness was to be ascribed. On that view the maximum hardness should be observed in binary alloys (gold with silver or copper), which formed an uninterrupted series of solutions, when 50 per cent. of each constituent was present, and that was invariably found to be so. As long as there were present few B atoms of small atomic weight, they would undergo much change, and the A atoms little change. As the B atoms became more numerous, the change of atomic volume and the increase of hardness would become smaller and smaller; for completely isomorphous metals the hardness curve should hence be parabolic with a flat maximum at 50 per cent. composition. Now Desch had pointed out (Transactions, Faraday Society, 1915, page 521) that the atomic volumes of metals which formed uninterrupted series of solid solutions were in all cases very close to each other, and the mean atomic volume would therefore undergo very little change from end to end. In developing a simple formula for these relations, Mr. Thompson suggested that the hardness of a metal was determined by its intrinsic pressure (Traube). Dr. Desch subsequently objected that he could not form any clear view of Traube's intrinsic pressure, which would, moreover, fit alloys which were not solid solutions; but Mr. Thompson replied that his results agreed with Traube's.

From the point of his hypothesis, Mr. Thompson continued, it was immaterial which of the two metals had the larger atomic volume; the solid solution of the two would in all cases be harder than either constituent. In this conclusion he differed from Roberts-Austen, who, on the strength of his first researches of 1888, on gold alloys, had maintained that metals which diminished the tenacity and extensibility of gold had higher atomic volumes than gold, whilst those which increased these properties had the same or lower atomic volumes. But according to Roberts-Austen's own work, aluminium, iridium and lithium (all of high atomic volume, yet increasing the tenacity of gold) behaved abnormally, and Arnold and Jefferson had shown in 1894 and 1896 that the atomic volume did not have the direct influence suggested. By studying the microstructure of alloys (gold with lead, bismuth, tellurium), Arnold proved that fragility resulted when each gold crystal was isolated from its neighbours by a cell-wall of the other metal, and that in iron (atomic volume 7.2) the addition of nickel, copper, aluminium, phosphorus, always produced hardness—so long as the second element passed entirely into solid solution—though the atomic volumes of these elements were 6.7, 7.1, 10.5, 13.5. The importance of the atomic volume came in in another way, Mr. Thompson proceeded. Silver and gold had practically the same atomic volumes, 10.23 and 10.20, and formed solid solutions in all proportions (as stated); silver and lead (atomic volumes 10.2 and 18.2) formed a series of eutectoids without appreciable miscibility at either end, and in Arnold's iron alloys—carbon, arsenic, and sulphur (atomic volumes 3.6, 13.2, 15.7) caused the separation of phases. These observations were in accordance with Mr. Thompson's view that in a solid solution there was a progressive replacement of the atoms in the space-lattice. Elements of similar atomic volumes would readily replace one another, and thus easily enter into solid solution. When the atomic volumes differed considerably, solid solutions would not be formed. That same theory would account for the extreme hardness of compounds of metals with metals. The interpenetration of the space-lattices would induce in them similar changes in atomic volume, and set up elastic stresses. But as a certain rigidity had to be assumed in the space-lattice of a compound, these compounds would not only be hard, but also brittle.

That many of the leading ideas of these arguments originated with Dr Beilby, Mr. Thompson accentuated more particularly in his second paper. At the conclusion of his first paper he referred to a recent similar paper by Tammann on "The Molecular Structure of Solid Isotropic and Anisotropic Binary Mixtures." In his second paper on "The Annealing of Metals," Mr. Thompson pointed out that the deformation of the space-lattice as a result of mechanical stress was the first step in the formation of the amorphous modification, and the cause of the increased hardness had to be sought in the amorphous material. That material was either itself very hard, or, what looked more probable, it was the seat of internal stresses. Annealing produced a recrystallisation of the deformed structure, and disappearance of the amorphous modification. On that theory the crystalline elements persisting after severe cold work should be no harder than the crystals had been before; that was so, according to Faust and Tammann. Two other theories had been proposed to explain the facts. According to Smits, the applied pressure produced irreversible molecular transformations, so that the physical structure remained different after removal of the stress. According to Tammann, tension stresses were set up in the planes of slip, and the greater the stress applied, the greater the number of slip planes and the hardness, ductility being on this view a function of the number of slip planes per unit volume induced by a constant stress. The practical aspect of the annealing problem, Mr. Thompson thought, had received less consideration in English publications than on the Continent. This statement caused Sir Robert Hadfield, the President of the Faraday Society, to remark that they had, in England, possibly been too ready to rely on Continental research, but he could assure the meeting that the Advisory Council on technical science had taken up its duties in a thorough and energetic manner, and funds would be at disposal for research.

The annealing of cold-worked metals or alloys (brass, nickel-silver), Mr. Thompson continued, was essentially distinct from the annealing of steel. In the latter case the objective was the removal of stresses due to casting or quenching, the equalisation of composition, and the refinement of coarse grain; the elastic limit should be maintained as high as possible. When brass cartridge-cases had to be annealed after cold work, it was to make them capable of receiving further changes of shape. The work required to produce these further changes was first used in causing elastic deformation—which was small and transient, disappearing immediately the stress was removed, and this energy was really wasted; and, secondly, in causing the required plastic deformation; thus, the higher the elastic limit the greater was the percentage of energy lost in useless effort; an almost non-existent elastic limit was the desideratum. That fact complicated the annealing of brass; the annealing was to admit of a further maximum reduction in the rolls or in wire-drawing, and for that purpose re-heating above the temperature at which recrystallisation took place was required. To illustrate his point Mr. Thompson gave particulars of experiments with a low-grade nickel-silver (9 per cent. of nickel), which, annealed for half an hour at gradually increasing temperatures of 300, 370, 440, 510, 580, 720, 785, 930 deg. Cent. in a gas-fired muffle, gave Brinell hardness numbers of 130, 143, 127, 119, 86, 80, 65, 52, 50; hence softening began at 370 deg., but was not complete until the temperature reached 800 deg. With a 70/30 brass Charpy had similarly found, at temperatures of 200, 280, 420, 560, 600, 832 deg. Cent., maximum stresses (in kilogrammes per sq. mm.) of 49.5, 51.2, 46.5, 34, 30, 27.5, 27.5.

When comparative annealing experiments of alloys and of metals were made, it was found that the alloy required much higher temperatures than the metal, and the range over which the softening extended was much greater in the case of the alloy. In the case of the nickel-silver the range extended from 370 up to 800 deg. Cent., whilst Beilby had softened pure copper within a range of 50 deg., an observation which Charpy had confirmed for copper. There was, further, a noteworthy slight increase in the hardness curves of the copper and alloys just before the commencement of softening; this feature Mr. Thompson had found to be general.

According to Charpy, annealing practically did not affect the properties of cold-worked brass up to a certain temperature; then recrystallisation, first probably of those crystals which had been most distorted, set in, and continued up to total crystallisation at a certain higher temperature. To complete the heat treatment, however, a still higher temperature had to be applied, and there was danger of burning. The burning had a two-fold effect: it induced coarse crystallisation and mechanical weakness, though such a metal, as Hudson had shown in 1913, would roll satisfactorily; but there was also fusion and volatilisation of the more volatile metal, which was particularly noticeable in the presence of certain impurities. Thus Charpy found that brass was not deteriorated at 900 deg. Cent., but began to burn at 800 deg. in the presence of 0.2 per cent. of lead and 0.15 per cent. of tin. The tests of this impure cartridge brass yielded, at 540, 620, 700, 860, 930 deg. Cent., a maximum stress (kg. per sq. mm.) of 62, 32, 30, 29.3, 27.6, 26.5, and an elongation of 3.8, 55, 61, 65, 57, 56.5 per cent. The loss of tensile strength caused by recrystallisation was at first accompanied by an increase in the elongation. When burning occurred, strength and ductility both decreased, and in such brass pits (from the volatilisation of the zinc) appeared, which finally developed into fissures. The time factor, *i.e.*, prolonged annealing at low temperature, or rapid heating to a higher temperature was unimportant according to Charpy and Le Chatelier, for wires, strips, and small ingots. For larger samples some time had to be allowed for the conduction of the heat, but the prolonged soaking, occasionally recommended, was probably unnecessary in Mr. Thompson's opinion. The time factor was important for working at comparatively low temperatures, which were of little technical interest, however. Thus hard-rolled copper required an hour's soaking at 200 deg. Cent. for total annealing, but was completely softened in a minute or two at 350 deg. Cent. (Le Chatelier). The diminution of electric resistance and of hardness generally went together in brasses, nickel-silver and other alloys, and also in pure metals. Nickel-silvers of 28 per cent. nickel, however, did not diminish their resistance when annealed, and there was also a peculiar peak of high resistance in all nickel-silvers of more than 15 per cent. nickel, between 320 and 400 deg. Cent. The minimum resistance observed in nickel-silver of 7 per cent., at 400 deg. Cent., on the other hand, had also been noticed by Credner in many metals—silver, gold, copper, iron, nickel. Sir Robert Hadfield and Dr. Desch commented upon the importance of these communications by Mr. Thompson.

A note by Dr. R. Seligmann and Mr. Percy Williams on the "Annealing of Aluminium" concerned further evidence of changes produced in aluminium at the comparatively low temperature of 125 deg. Cent. Lowry and Parker had observed that hard-worked aluminium (filings) decreased in density when heated up to 100 deg. Cent. Dr. Seligmann has studied the technically-important attack of aluminium by nitric acid. The attack, he explained, was very slight, the loss of aluminium amounting to about 56 milligrammes per 100 sq. cm. per twenty-four hours, but the corrosion did not stop after a time; heating to 125 deg. Cent. for ten hours reduced the attack by 5 per cent., heating to 500 deg. Cent. by 30 per cent. The rate of dissolution did not diminish on prolonged heating (for eighty hours) at 125 deg., but when the metal was annealed at higher temperature (440 deg. Cent.) the loss of weight in nitric acid was first smaller than when the metal had been allowed to stand for several days after annealing. Aluminium is, broadly speaking, believed not to oxidise in the air, even when hot, and not to be attacked by nitric acid; as a matter of fact it covers itself with a very fine protective film of oxide. In view of these facts, Dr. Borns asked whether the fine oxide film might not have some influence on the corrodibility by nitric acid, but Dr. Seligmann replied that he had guarded against such influences. Dr. Seligmann did not explain his observations by proposing any allotropic modification of aluminium; but Dr. F. J Brislee did so in a paper, also read last Tuesday, on "The Specific Heat of Hard and Soft Aluminium," a continuation of his former work on "Changes in Physical Properties of Aluminium with Mechanical Work." We mention two more papers, likewise brought before this meeting, of a somewhat cognate character. Mr. E. J. Hartung, B.Sc., of Melbourne, presented a "Contribution to the Theory of Solutions," giving some valuable information about the contraction and other changes (heat capacity and heat in mixing) observed when two liquids (nitro-benzene and ether, aniline and ether, methyl alcohol or carbon tetrachloride) were mixed. Professor A. W. Porter, F.R.S., welcomed the new experimental material, but could not accept the interpretation of the results, which Mr. Hartung bases on a modification of the law of mass action proposed by Denison when engaged in similar researches. The contraction curves of mixed liquids of Mr. Hartung resembled hardness curves of solid solutions, and Mr. Emil Hatschek had in his paper—the first one read—on "An Analysis of the Theory of Gels as Systems of Two Liquid Phases" dealt with gels (gelatinised colloids) and their stresses somewhat in the way that the metallurgists would adopt for a theoretical investigation. A paper on "Grain Size Measurements," by Mr. Zay Jeffries, Met.E., also discussed by the Faraday Society last Tuesday, will be noticed on another occasion.

NOTES.

London Association of Foremen Engineers.

Sir Robert Hadfield presided at the sixty-third annual dinner of this Association at Cannon-street Hotel on Saturday, the 6th inst., and in the course of his speech, speaking as a working and managing engineer, or head-foreman himself, he expressed the pleasure he felt in meeting so many foremen engineers who were taking a most important share in helping our Empire and Allies in this the hour of danger and stress. The success of any large munitions works depended to a great extent upon the way in which the foremen handled their daily production. Millions of operatives were engaged in munition manufacture of all kinds, and amongst those millions no set of men in the Empire had done more to help on the work than the foremen engineers of this country. He (Sir Robert) could speak upon the point from personal knowledge, since in his company's works at Sheffield there were nearly 250 foremen, managers, or superintendents, and a better, more hard-working, and more self-denying set of men it would be impossible to have. A foreman engineer's lot was not always a pleasant one. He was often the "buffer," but he succeeded admirably in that or any other position. If the questions to be dealt with had reference to the turning out of more work, or to reducing cost, or again to any matter concerned with wages or shop disputes, the foreman was invariably sent for. His (Sir Robert's) experience extended over some forty years, and he never remembered one single case of unwillingness to help on the part of any foreman with whom he had come in contact, no matter how difficult the problem presented for solution. When the present conflict was over, added Sir Robert, the difficulties to be then faced would most probably exceed those of the present time, and without the aid of the foremen there could only be chaos in the works. He therefore earnestly begged the foremen one and all to be giving this problem every possible consideration; the foremen were often the ambassadors between employer and employed, and could do much to help. By the exercise of tact and goodwill between man and man, such as the foremen had shown in the past, he had every confidence that the coming difficulties would be surmounted.

Transmutation of Chemical Elements?

The powerful effects of cathode-ray bombardments have induced W. P. Jorissen and J. A. Vollgraff, of the University of Leiden, to determine whether they could induce radioactivity or photographic activity by such bombardments, or possibly cause a transmutation of the elements. A certain activation of metallic salts by cathode rays had repeatedly been observed. An account of the research, so far carried out with the aid of the Institut Physique de Solvay, appeared in the *Zeitschrift für Physikalische Chemie* of December, 1914, and November, 1915, vol. lxxxix., page 151, and vol. xc., page 557. Jorissen and Vollgraff first tried uranium oxide (U_3O_8), which was placed in a dish of Jena glass on an anode of platinum, the cathode of their bulb being of aluminium; currents of up to 4 milliamperes were used, the gas pressure in the bulb being below 0.05 mm. There was no visible change apart from a colour change, the grey oxide turning black; the grey colour could be restored by heating the oxide in oxygen, and it is very probable that the U_3O_8 had given off some oxygen under the cathode-ray bombardment. But the radioactivity of the oxide, as tested by the electroscope, was not changed, and that had been the chief object of the experiment. The investigators then took bismuth. P. Villard had observed in 1900 that bismuth was photographically active after bombardment; he did not state, however, whether there had not been any activity before the bombardment, and Jorissen and Ringer had not been able to confirm his observation in 1907. For the new experiments they placed the powdered bismuth again in a glass dish; the glass broke, however, and the bismuth fused, evaporated, and formed a bismuth mirror on the wall of the bulb. The glass was then replaced by quartz. The treatment did not render the bismuth at all radioactive, nor did the metal act on a photographic plate, as Villard had stated. The chemical analysis by Schoorl showed that the original bismuth had not contained any thallium; traces of calcium and also of potassium and sodium were, however, found in the bismuth mirrors, and these metals were probably due to a contamination by the glass of the bulb. These chemical analyses were supplemented by spectroscopic tests, and then a trace of thallium was discovered in the untreated bismuth; the thallium lines were faint, however, and were not any stronger in the treated metal than in the untreated metal. The presence of these traces of thallium is not surprising; Herapath proved in 1863 that thallium is a frequent companion of bismuth, and this was confirmed by Sir W. Crookes, the discoverer of thallium. The reasons for the search for thallium is that the atomic weight of bismuth is 208 and that of thallium 204; the two atomic weights thus differ by 4, which is the atomic weight of helium. The idea was that the cathode-ray bombardment might expel an α ray (a helium atom) from the bismuth. It may be objected, however, that the treatment only lasted a few periods of four hours or less. Radioactive phenomena, it is known, are not affected by the ordinary changes in temperature, pressure, &c., producible in the laboratory; extraordinary violence might have effects. It might also be mentioned that the atomic weight of bismuth was some years ago supposed to be 208.5, and that some chemists again favour this value, whilst the international tables give the weight as 208.0.

Personal.—The Society of Motor Manufacturers and Traders, Limited, have appointed Mr. T. C. Pullinger, of Arrol-Johnston, Limited, to represent the Society upon the Electric Vehicle Committee.

Association of Supervising Electricians.—The meeting of this Association announced for May 16 will not take place owing to Mr. F. C. Raphael having accepted a commission in the Royal Engineers. Other arrangements are being made, and of these due notice will be given.

Engineering Industry in the Economic War.—Under the auspices of the Institution of Engineers and Shipbuilders in Scotland, the West of Scotland Iron and Steel Institute, and the Glasgow Chamber of Commerce, an address on Engineering Industry in the Economic War will be delivered by Mr. T. C. Elder (British Electrical and Allied Manufacturers' Association), who will be followed by other speakers, in the Lecture Hall of the Royal Technical College, Glasgow, on Tuesday, May 16, 1916, at 2.15 p.m.

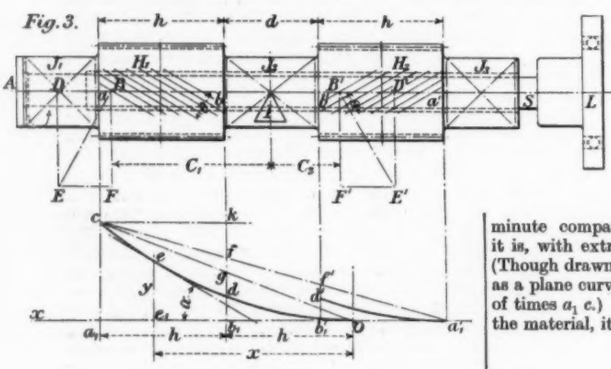
Royal Institution.—A General Meeting of the Members of the Royal Institution was held on the afternoon of Monday last, the 8th inst., Sir James Crichton-Browne, Treasurer and Vice-President, in the Chair. The Secretary announced that His Grace the President had nominated the following gentlemen as Vice-Presidents for the ensuing year: Sir Thomas Barlow, Bart., Sir William Phipson Beale, Bart., Mr. Charles Hawksley, the Hon. Richard Clere Parsons, Sir James Reid, Bart., the Right Hon. Lord Wrenbury, Sir James Crichton-Browne (Treasurer), and Colonel Edmond H. Hills (Secretary).

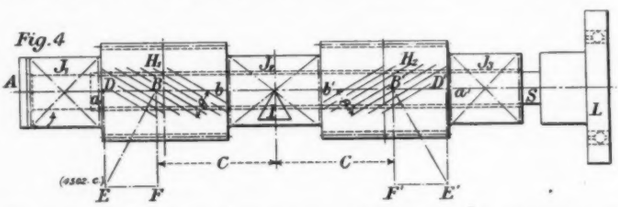
ON REDUCTION GEARS.

By JOHN H. MACALPINE.

(*Continued from page* 417.)

(*b*) *Torsional Yield.*—Fig. 3 shows a pinion with three journals, J_1, J_2, J_3, also right and left-hand helices at H_1 and H_2; but what follows applies equally if the helix H_1 were made left-hand and H_2 right-hand. The pinion is driven from the end A in the direction which makes the near side rise. The torsional yield of the pinion will make the teeth at *a* advance slightly on those at *b*; and similarly those at *b'* advance on those at *a'*. Thus the centre of pressure in both helices will, if the pinion axis is held by rigidly-mounted bearings, move toward A, to points represented by B and B', and the pressure on the bearings will be very unequally distributed between them. The resultant forces, B E and B' E', will be practically normal to the tooth surfaces at contact, and thus the angles D B E, D' B' E', may be taken as equal to the helical angle of the teeth at the pitch line. The axial components B D, B' D' are equal, as the pinion is always given free end play and the equality of these forces determines its position. If they are unequal for an instant, the difference would produce a slight axial movement accompanied by a slight rotation about the pinion axis. Therefore B E = B' E' and B F = B' F', and each helix must transmit half of the power. The whole torque, then, transmitted through *a* has fallen to one-half this value at *b* and *b'* and to zero at *a'*, whatever the distribution of tooth pressure. If the teeth were rigid, we should have point contact at *a* and *b'* and opening of contact at *b* and *a'*.





As in the case of cross-bending, let us proceed by supposing uniform distribution of tooth pressure and find what yield this would produce. If it closely approaches $\frac{1}{100}$ in. in the illustration to be taken, we may be sure that this initial supposition is seriously upset and that the load on the teeth will be much concentrated.

The torsion of the middle journal has no effect on the distribution of tooth pressure, or when torque is applied helix H_1 will advance as a whole, in rotation, on Helix H_2, due to the torsion of journal J_2. This will relieve the pressure on the teeth of H_2 and, as B D will then be larger than B' D', the teeth of H_1 will slide infinitesimally on the gear-teeth by a combined rotation and an axial translation of the pinion to the left, and the tooth contacts of H_2 will again close, the forces B D and B' D' becoming equal. This would leave precisely the same intensity and distribution of tooth pressure as would have held had J_2 been rigid, as we will now assume.

[It is important to note in passing that this shows clearly the necessity for helical teeth. If we use spur-gears, the forces B D and B' D' are zero and no axial movement is produced. But even if it were, this would not close up the tooth contacts of H_2, and the power would be transmitted principally or altogether by H_1. Besides, if in machining the teeth those of H_1 were not in exact line with those of H_2, they could not be made to lie fairly on the gear-teeth, unless the same error had been made in these, which is entirely improbable. In helical gears a slight error of this kind, being equivalent to torsion of J_2, is of no importance, as we have just seen.]

Suppose a line *a b b' a'* drawn along the unstrained pitch surface. (We may suppose the helices are cylinders of pitch diameter, but that in some way the torque due to the tooth pressure is still applied.) When torque is applied this straight line will be changed to a curve made up of two parts *c d*, *d' a'*$_1$, which, for clearness, is shown below the pinion drawing with the vertical scale extremely exaggerated. As J_2 is supposed rigid, the yields b_1 *d* and b'_1 d' are equal. The torque is zero at *a'*, the free end of the pinion, and as tooth pressure is supposed uniform, the torque increases at a uniform rate from *a'* to *b'* and at the same rate from *b* to *a*. Hence, if the portion *d' a'*$_1$ is moved to the left till *d'* and *d* coincide, we shall have a continuous curve *c d* O. The *rate* of distortion or twist at any section is proportional to the torque at that section, and this rate is measured by tan *a*, where *a* is the angle which the tangent at any point *e* makes with O a_1. As the torque is zero at O, the rate of twist and tan *a* are zero also, so that the curve is tangent to O a_1. Since tan *a* is proportional to O e_1, the curve, as is well known, is a parabola; and as the arc Oc is minute compared with the radius of curvature, it is, with extreme accuracy, a portion of a circle. (Though drawn on the pitch cylinder, I speak of it as a plane curve, since the pitch radius is thousands of times a_1 *c*.) Taking μ as the rigidity modulus of the material, it can readily be shown* that

$$e\,e_1 = \frac{4\,w}{\pi\,\mu}\left(\frac{x}{D}\right)^2 \quad . \quad . \quad . \quad (6)$$

where

$$x = O\,e_1;$$

and, consequently, putting

$$x = O\,a_1 = 2h,$$

$$a_1\,c = \frac{16\,w}{\pi\,\mu}\left(\frac{h}{D}\right)^2 \quad . \quad . \quad . \quad (7)$$

As before, put

$$D = 14'',\ h = 20'',\ \text{and}\ P = 6000.$$

$w\,h$ = 18,010 lb. for 1500 r.p.m. of pinion.

Also take

$$\mu = 12 \times 10^6 \text{ lb. per sq. in.}$$

Equation (7) gives

$$a_1\,c = 7.80 \times 10^{-4} \text{ in.}$$

Also

$$b_1\,d = \frac{a_1\,c}{4} = 1.95 \times 10^{-4}.$$

In helix H_1 the distance measured circumferentially, or opening of contact, which the spring of the teeth has to close at *b* is

$$d\,k = a_1\,c - b_1\,d = 5.85 \times 10^{-4} \text{ in.}$$

In helix H_2 the opening of contact at *a'* is only

$$b'_1\,d' = 1.95 \times 10^{-4} \text{ in.}$$

The disturbance of distribution of tooth pressure in helix H_1 will be very sensible, and the displacement of the centre of pressure B, from the centre of H_1 towards *a*, will be considerable. That of B' towards *b'* will be much less.

The conditions shown by Fig. 3 cannot exist if a floating frame is adopted. Whether the floating frame is supported by an I-beam, as in the article already referred to, or by pistons under the bearings, as proposed by the late Mr. Geo. Westinghouse (see ENGINEERING, vol. xcii., page 663), the condition is introduced that the moments of all forces acting on the teeth must be zero about the point of support I at the middle of the pinion length. This is not true in Fig. 3, as the leverages C_1, C_2, of the equal forces B F, B' F', are very unequal. As a result the pinion and floating frame would tilt infinitesimally, falling at the end A, to relieve the hard pressure of the teeth near *a* and *b'*. The conditions shown in Fig. 4 would be automatically established, the points of resultant pressure B, B' being equally distant from I—not necessarily at the centre of length of each helix, but, for a well-proportioned pinion, no doubt very close to these centres. This tilt of the floating frame would diminish the opening of contact at $b = d\ k$; it would change the conditions in H_2 by opening the contact at *b'* and closing it at *a'*. It will be instructive to examine the action closely.

If the pinion only had teeth at *a* and *a'*, it would tilt till the chord C *a'*$_1$ was forced parallel to the gear axis. But the arc *a'*$_1$ *d'* meets this chord at *a'*$_1$ at a very slight angle and lies very close to it all along, so that a minute yield of the teeth will bring all those in helix H_2 into contact with nearly uniform distribution of pressure, and the resultant force B' F' would only be displaced from the centre of H_2 slightly towards *a'*. But in helix H_1 the chord C *a'*$_1$ meets the arc *c d* at *c* at an angle which, as shown in the figure, is nearly three times that at *a'*$_1$. Hence the tooth contacts in H_1 would not close so readily and the point of resultant pressure B would still be close to *a*. Obviously the residual moment from these tooth pressures would tilt the floating frame further, causing B' to recede from I, and B to approach it.

It would be possible, but of no practical utility, to calculate in an ideal case what the actual tilt would be. It is, however, of value and quite easy to set the limit beyond which it will not pass:—The asymmetry of the arcs *c d*, *a'*$_1$ *d'*, with respect to the chord *c a'*$_1$ is due to the length of the middle bearing. If we reduce to two bearings, moving H_2 up to join H_1, the arcs are, as above, now represented by the continuous curve *c d* O, and the chord *c a'*$_1$ by *c* O. This arc and chord meet at equal angles at *c* and O, and the two-bearing floating frame would tilt till *c* O is parallel to the gear axis. The tilt of a three-bearing pinion is obviously between these two limits. For the minimum tilt the opening of contact at *b* is *d f*, and for the maximum tilt it is *d g*, while that for a rigid gear is *d k*. If *d* is the distance between the helices,

$$f\,k = a_1\,c \times \frac{h}{2\,h + d},$$

and

$$g\,k = \frac{a_1\,c}{2},$$

since for this $d = 0$.

Also $g\,d = b_1\,d$ (as *a* is minute) $= \frac{a_1\,c}{4}$, as shown above; and as $d\,k = \frac{3\,a_1\,c}{4}$, the floating frame for a two-bearing gear reduces the opening of contact at *b* to one-third of its amount for a rigid gear of the same dimensions of pinion.

In the foregoing example at 6000 horse-power the present practice of the Westinghouse Machine Company would make the centre bearing 14½ in. long and $d = 15$ in. This gives

$$f\,k = \frac{7.80 \times 10^{-4} \times 20}{55} = 2.84 \times 10^{-4},$$

* Let T_c = torque at e_1, and T_a = torque at a_1.

f = shearing stress at the surface at e_1.

$$T_c = \frac{\pi}{16} f D^3.$$

$$T_a = w \times 2h \times \frac{D}{2}.$$

$$\therefore\ T_c = \frac{w\,D}{2} x.$$

$$\therefore\ f = \frac{8\,w\,x}{\pi\,D^2}.$$

Rates of distortion = $\tan a = \frac{d\,y}{d\,x} = \frac{f}{\mu} = \frac{8\,w\,x}{\pi\,\mu\,D^2}$.

$$\therefore\ y = \frac{4\,w}{\pi\,\mu}\left(\frac{x}{D}\right)^2.$$

$d f = d k - f k = (5.85 - 2.84)\ 10^{-4} = 3.01 \times 10^{-4}$
$d g = b_1 d \qquad = 1.95 \times 10^{-4}.$

Thus we may be sure that in this particular case the floating frame reduces the opening of contact due to torsion to between one-half and one-third of its value for a rigid gear.

[The reader can readily prove that $d' f' = 0.89 \times 10^{-4}$. Also that the greatest circumferential distance from arc $d' a'_1$ to the chord $c a'_1$ is 1.03×10^{-4}. Thus the arc almost coincides with the chord.]

The foregoing, together with the case of the 14-in. pinion at 12,000 horse-power and 1500 revolutions per minute, are gathered into the following table. I have also added the previously calculated values for cross-bending for a three-bearing gear and the power constant:—

Horse-power	6000		12,000	
Pinion diameter ..	14 in.		14 in.	
Revolutions per minute of pinion	1500		1500	
Power constant ..	1.458		2.916	
Gear	Rigid	Floating frame	Rigid	Floating frame
h	20 in.	20 in.	28 in.	28 in.
d	Immaterial	15 in.	Immaterial	22 in.
Opening of contact at b due to torsion ..	5.85×10^{-4}	Between 3.01×10^{-4} and 1.95×10^{-4}	16.38×10^{-4}	Between 8.54×10^{-4} and 5.46×10^{-4}
Opening of contact at the centre of helix due to cross-bending	3.43×10^{-5}	3.43×10^{-5}	1.88×10^{-4}	1.88×10^{-4}

In a two-bearing pinion the errors due to cross-bending and torsion are additive, as both reach their maximum midway between the bearings. In a three-bearing pinion they are not additive, as the points of maxima do not nearly coincide; but taken together they conspire to concentrate the tooth pressure towards a and a'.

The above table seems to indicate that, judging from torsion alone, a power constant of 3 is very excessive for a rigid gear, and the actual values given later do not contradict this. But it also shows that, with a floating frame, this value is moderate, and this I will confirm from experience. But we may conclude from the table that in making the helix ratio $h/D = 2$ we have come very near to, and may have slightly surpassed, the best value.

In judging of the effects of these errors it should be borne in mind, as stated above, that the fitting of the teeth, by scraping or grinding, is usually finished under some considerable torque, not infrequently under full load. Hence at least a part of the effects of these errors may be counteracted. But the variations of these errors under varying load remain, and if the calculated values are large these variations are large also. It is surely a great advantage to have these errors as small as possible, and thus to know that if the teeth fit well at any load they will do so at all loads up to the maximum. Besides, we have yet to deal with errors of alignment, which may change suddenly and accidentally at any time, and from which, consequently, there is no such way of escape even partially open.

It should be noted that if we set out by settling the load per inch on the teeth, w, and the diameter of the pinion, then calculate the length $2h$ necessary to transmit the required power, equation (7) shows that the torsional yield rises as h^2, and we might readily get into trouble. This procedure is practised by some manufacturers and has, I know, led to serious trouble. I call special attention to this because Messrs. McLaren and Welsh proceeding thus in a considerable number of cases propose helices more than two diameters in length; but this drew out no remark in the discussion. They are not alone in hoping that the elasticity of the bearings may be a sufficient corrective of the torsional yield. They state: "In actual gears, however, this condition of rigidity at the bearings is not realised, and the pinion journals may yield sufficiently to bring an approximately equal intensity of load over all the teeth. In any case the distortion due to torsional strain is almost negligible." On this I would remark:—

1. In rigid gears we must depend on the great rigidity of the bed-plate (gear-housing) to keep the gear and pinion-shafts sufficiently in line whatever varying external forces may act on it, but the above anticipates that they will sufficiently alter their alignment under *differences* of loads on the pinion journals which are a small fraction of the total load. These conditions are clearly opposed. If sufficient elasticity of the bed-plate is allowed, the shafts will easily be put out of proper line by any accidental circumstance. The floating frame provides that the smallest forces will allow the pinion to change its alignment, but it holds the bearings in line most rigidly.

2. If journal J_1, Fig. 3, falls relatively to journal J_2, it must be due to a greater increase of load on J_1 than on J_2; that is, the point B of resultant force on the teeth of H_1 must be nearer a than B′ is to a'; the moments of the journal forces and, of course also, those of B F and B′ F′ are then not zero about the central point I, which we have seen is a necessary condition for good distribution of tooth pressure. Thus the elasticity of the bed-plate cannot supply the desired condition and, further, any added elasticity of the bearings cannot supply it either. This latter was fully considered before the floating frame was adopted. A moment's thought will show that the same reasoning applies to any attempt to solve the problem by making short lengths of the teeth of the large gear springy, as has been proposed. In one case I know it led to failure and the replacement of the reduction gear.

3. As I have shown, the distortion due to torsional strain is, in many cases, far from negligible. It is a very important factor.

(To be continued.)

METALLURGY AND THE ADVISORY COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH.

THE first meeting of the Standing Committee on Metallurgy appointed by the Advisory Council for Scientific and Industrial Research, was held on Monday, the 8th instant. The Committee consists as to one-half of members nominated by the professional Societies concerned, the other half being appointed direct by the Advisory Council, and has been constituted with a view to the representation of both the scientific and the industrial sides of the industries.

The Committee was welcomed by Sir Willaim M'Cormick, Chairman of the Advisory Council, and Dr. H. F. Heath, Administrative Secretary to the Council. Sir Amherst Selby-Bigge, Secretary to the Committee of Privy Council for Scientific and Industrial Research, also attended and gave an account of the genesis of the movement and emphasised the importance which the Government attach to the establishment of close relations between education, research and industry. Sir Gerard Muntz, Bt., is Chairman of the Committee and of the section on the Metallurgy of Non-Ferrous Metals, and Sir Robert Hadfield, F.R.S., is Chairman of the Section on the Metallurgy of Ferrous Metals. The members appointed up to the present are as follows:—

Standing Committee on Metallurgy.—Professor J. O. Arnold; Mr. Arthur Balfour; Professor H. C. H. Carpenter; Dr. C. H. Desch; Sir Robert Hadfield; Mr. F. W. Harbord; Mr. J. Rossiter Hoyle; Professor Huntington; Mr. W. Murray Morrison; Sir Gerard Muntz, Bt.; Mr. George Ritchie; Dr. J. E. Stead; Mr. H. L. Sulman; Mr. F. Tomlinson.;

Section on the Metallurgy of Ferrous Metals.—Sir Robert Hadfield (Chairman); Professor J. O. Arnold; Mr. Arthur Balfour; Professor H. C. H. Carpenter; Dr. C. H. Desch; Mr. F. W. Harbord; Mr. J. Rossiter Hoyle; Professor Huntington; Mr. George Ritchie; Dr. J. E. Stead.

Section on the Metallurgy of Non-Ferrous Metals.—Sir Gerard Muntz, Bt. (Chairman); Professor J. O. Arnold; Professor H. C. H. Carpenter; Dr. C. H. Desch; Mr. F. W. Harbord; Sir Robert Hadfield; Professor Huntington; Mr. W. Murray Morrison; Dr. J. E. Stead; Mr. H. L. Sulman; Mr. F. Tomlinson.

In his opening statement as Chairman of the Ferrous Section of the Metallurgical Committee, Sir Robert Hadfield called attention to the need in research no less than in industry for co-operation so far as may be consistent with the freedom of individual workers, and to the particular necessity for improvement and progress in the matallurgy of iron and steel. Though Great Britain had been far from backward in this field, there was now room for a great extension of research in which there would be a happy combination of science and practice. The value of what he described as untrained foresight was rapidly diminishing owing to the many scientific developments now constantly taking place, and they would not any longer rely upon other than purely scientific methods, because science itself had advanced so greatly during the last three decades. The success of great improvements in metallurgy had often hung upon a slender thread; the Bessemer process was not a success in a commercial sense until the refractory materials capable of resisting the high temperatures developed in the process were found to be available in Sheffield. The further progress of metallurgy depended largely on the securing of supplies of the special alloys and materials required, and there was now need for a central clearing house in order that as soon as new knowledge was secured as to valuable products in any part of the Empire it should be made available for British industry. No foreign control of such products, either directly or indirectly, should any longer be permitted. Sir Robert Hadfield called attention to the series of special reports on the mineral resources of Great Britain now being issued by the Geological Survey, and urged that similar information for the whole Empire should now be made available through one central source. As regards experimental research, it was essential to make the best use of all existing organisations in this country, and in this connection the position of Sheffield in the metallurgy industry and of the Sheffield University in the domain of metallurgical research was emphasised. Sir Robert Hadfield directed attention to a number of subjects upon which more light was needed, for example, the production of sound steel; the discovery of new alloy steels and the development of the older types; wider study of crystallised structure and examination by photomicrography with increased magnifications; more accurate determinations of high temperatures, including the improvement of electrical and optical pyrometers; the improvement of electrical-furnace practice; the improvement of methods of hardening; the improvement of the permeability and other electrical and magnetic qualities of various alloys and the correlation of the mechanical and magnetic properties of steel; corrosion; refractory materials, especially with a view to rendering ourselves independent of foreign supplies.

NOTES FROM THE UNITED STATES.

PHILADELPHIA, April 27, 1916.

A MARKED feature of the situation during the past few days is the falling off in the number of inquiries for future deliveries. This will have no influence whatever as the volume of business is beyond all precedent and there is every reason for believing that a revival of demand may set in at any time; besides, there are rumours that England and France feel themselves less dependent upon America for future supplies than a few months ago. The mills have orders on their books for shell and shrapnel steel running far into 1917 delivery, and wonderful things may happen before those orders are completed. Business has been recently placed for about 250,000 tons for shells. American makers are already discounting the possibility of the termination of the war within a year. The railroads have begun purchasing much structural material for building purposes and bridge work, and this has been supplemented during the past few days with numerous inquiries and orders from industrial sources mainly for plant extension. During the past 10 days orders for steel rails, including the Pennsylvania, have approximated 500,000 tons. The steel makers are anticipating an extensive European demand to compensate for the losses due to war. Heavy contracts have just been placed for pig iron for steel purposes, especially in the Pittsburg district. A number of furnaces have been blown out in order to make repairs; this will noticeably lessen the output for some time to come. Plate continues extremely active, and railroads are buying heavily; not a single evidence in slacking up is observable in any quarter. The railroads are again rushing in orders for locomotives. The Republic Iron and Steel Company and the Bethlehem Steel Company have just contracted for 150,000,000 tons each of basic pig; other concerns are figuring upon very heavy orders. The smaller mills and engineering plants are very busy; machine tools are in great request. A continuance of present oversold conditions must of necessity continue.

LARGE NEW IRON WORKS IN SWEDEN.—The large new iron works at Oxelösund, an important port for shipment of Swedish iron ore, are being pushed ahead as far as circumstances will allow, the war having caused considerable delay in the delivery of portions of the plant. The works are located at the Alö firth, close to Oxelösund. The production of the new works is calculated to comprise 60,000 tons of foundry pig, 100,000 tons of coke, 6,500 tons of tar, 1,800 tons of sulphate of ammonia, 500 tons of benzole. One blast furnace and three stoves are erected and lined with fire-proof Swedish material, from the Höganäs-Billesholm Company. A coking plant with 60 ovens is approaching completion and the installations for handling the auxiliary products will be ready within the next few months. The benzole and ammonia plant is almost ready. An electric power-station is being erected, with three three-phase generators, each of 1,500 horse-power capacity. The generators, from the General Swedish Electric Company, will be direct-coupled to gas engines. The gas engines come from abroad; only one has so far arrived, but the other two are shortly expected. A large crane is being erected for the handling of iron ore and limestone. For the supply of the coking ovens with fresh water, if such cannot be obtained from deep borings, a distillation plant for salt water is being erected with a capacity of 40 gallons of water per minute. There are two gas-holders, one for blast-furnace gas has a capacity of 10,000 cub.m, and the one for coke-oven gas of 1,000 cub. m. There are two crushing mills for the blast furnace, with a capacity of respectively 60 tons and 100 tons per hour, the latter being intended for ore which can be more easily crushed. All the machinery is being worked by means of electricity. For the iron works a quay, 140 m. long, of reinforced concrete, has been constructed, on which there will be two cranes, capable of discharging 100 tons of coal each per hour; the depth of water at the quay is 7.5 m. A cable railway transports the coal from the quay to the coking works, and there are two railway lines from the iron works to Oxelösund railway station.

INDUSTRIAL NOTES.

WE are informed that the Executive of the Mining Association and that of the Miners' Federation will meet next week in a joint conference in London at the Government's request, with a view to consider what action can be taken to increase the production of coal to meet the nation's need for the Navy, the manufacture of munitions and trade requirements.

At a meeting of the Executive Council of the Operative Spinners' Amalgamation, held in Manchester on Saturday last, the 6th inst., it was announced that the ballot of the operative spinners of Lancashire showed 96.67 per cent. of the votes to be in favour of ceasing work in order to enforce the advance of 10 per cent. in wages demanded from the Master Cotton-Spinners' Federation. The notices to cease work are to be handed in on the making-up day of the working week commencing Monday, 15th inst. The ballot of the members of the Cardroom Amalgamation on the question of pressing or not their claims for a 10 per cent. advance was being proceeded with at the time of writing.

A meeting of the Durham Coal Trade Conciliation Board was held last week in Newcastle, to fix the wages of the Durham miners for the next three months. Wages were advanced 3¾ per cent. in February, making them 78¾ per cent. above the 1879 basis. They were last week advanced by 10 per cent., making them therefore 88¾ per cent. above the basis and the highest on record.

Last week also a conference of the South Wales miners was held at Cardiff, when it was decided by a large majority to accept the decision of the Executive Council and to apply for a 15 per cent. advance in the wage rate.

The Black Country Fire-Clay Wages Conciliation Board has granted an increase of 7 per cent. in wages to all underground workers, and an increase of 5 per cent. on the 1911 basis to the surface workers.

We are informed that the Darlington Munitions Training Committee held a meeting on Thursday, the 4th inst., to discuss the question of training girls for munition work. It was proposed to give the girls a course of 100 hours training in such work as they preferred in connection with munitions in order to qualify them for that work. The course is to take place at the Technical College, and the girls will have to sign an agreement to go wherever they are required by the Ministry of Munitions.

In connection with the above, it is interesting to note, according to the *Textile Mercury*, that the young women coming from the non-textile districts into the woollen-spinning rooms in Huddersfield are being placed under agreements with their employers. In the first place, the employer engages the learner definitely for a fortnight, paying her wages which, with war bonus, come to 16s. a week. The result of the experiment being satisfactory, he obtains her services for a definite period of six calendar months, subject to proper safeguards in the event of illness or wilfulness. The wages thereupon rise, and for the sixth and succeeding weeks the female piecer receives total wages of one pound. The payments are good and advancement is not precluded, for on rising to the position of leading-piecer, or deputy-minder, the wages may be augmented 20 per cent.

The necessity of a binding agreement for a specified period is apparent when it is considered that these persons have to be taught their trade, and may be tempted to leave their teachers as soon as the business has been learnt. But the bonds are in no way onerous. The learner gets from the beginning a wage upon which she can live, and she advances by short, sharp steps to a scale that may well content her fully. The women come from a distance, and in bringing them, the employers pay their railway fares, the amount of which is deducted from future earnings in sixpenny weekly instalments. The deduction is just, but in arranging it the employers make an offer of generosity, for contingently upon the learner satisfactorily fulfilling her contract, the deduction is to be refunded, and it is thus made to serve as a bonus upon good work. The scheme has been carefully designed to meet the real needs and the reasonable aspirations of the in-comers, and it deserves, for what it is worth, the notice of others who are driven by the shortage of male labour to introduce young women from beyond the usual radius.

Dealing again with the Tavenner Bill for prohibiting scientific shop management in the United States Government establishments, a brief account of which we gave on page 376 *ante*, the *Iron Age* says that the House Committee on Labour was going to undertake finally to dispose of it. The Committee referred to gave a hearing to Mr. W. B. Richards, Consulting Engineer, New York, whose statement concerning the Bill is as follows:—"I think it may safely be said that, in the opinion of the engineering profession and the manufacturing world, the Tavenner Bill could be properly entitled 'a Bill to penalise efficiency in the public service.' It undertakes to make a criminal of every officer of the United States who uses in a public establishment those methods which, in thousands of private plants and in the arsenals controlled by the War Department, have demonstrated over a period of years their unquestioned capacity at once to decrease the cost of production and increase the wages of the employees. As Thomas A. Edison, the dean of American inventors, says of the measure: 'It is an attempt to prevent efficiency and would be disastrous to labour and to the public.'"

It is announced that a ballot has been ordered among members of the Amalgamated Society of Engineers to select fourteen Parliamentary candidates for the next General Election. The nominations are forty-seven in number.

The conditions of labour in Denmark and Norway continue in an unsettled and unsatisfactory state, and a number of negotiations have been and are still going on. In Denmark a lock-out likely to have involved some 90,000 hands was luckily averted some little time ago, but a new lock-out, likely to affect some 40,000 hands, is at present threatening, although every endeavour is being made to stave off this outcome. In Norway the iron industry has come to a deadlock, the men insisting upon the mediation being stopped, and refusing to listen to the proposal of the national mediator to postpone their going out a few days. This means that the ship-building industry, manufacturing engineers, foundries, electrical industries, &c., have to stop work at a time when they are exceptionally busy. In the mining industry the conflict has already lasted for more than two months, affecting 5000 men, with 18,000 men in the iron industry, making a total of 23,000 hands. In addition some 7000 hands at the Norsk Hydro Company, the tinning concerns in Stavanger, the milk-condensing and match factories, have threatened a sympathetic strike, promising, however, to give a week's notice. The men's national organisation in the meantime has been empowered to extend the sympathetic strike to all branches that it may be found expedient to include.

Germany's attempt to obtain labour from Scandinavia has not answered its purpose, and is still less likely to do so in the future. Very few Norwegian hands have allowed themselves to be enticed, but a limited number of Swedes have gone to Germany, from whence, however, they are now returning, utterly dissatisfied, and the Swedish colony in Berlin is doing all in its power to put a stop to Swedish workmen going to Germany. Most of those who did go were sent to the ammunition works, and in the earlier part of the war matters were satisfactory enough, men earning as much as 120 marks in the week. Now, however, matters are completely changed. A large number of factories are only working 3 or 4 days a week for want of raw materials, and some have stopped work altogether. In addition, female labour is now being employed to an extent hitherto undreamt of. Altogether, German industry has hands enough. Another drawback is the exorbitant prices charged for what little food there is obtainable.

FLYING CORPS COMMITTEE OF INQUIRY.—On Monday last the Under-Secretary for War announced in Parliament that a Committee had been appointed to inquire into the administration of the Royal Flying Corps. It consists of Mr. Justice Bailhache (Chairman), Mr. J. G. Butcher, M.P., Mr. E. Shortt, M.P., Mr. J. H. Balfour Browne, K.C., the Hon. Sir C. A. Parsons, K.C.B., and Mr. Charles Bright. A military officer is to be invited to join the Committee.

BURMEISTER AND WAIN, COPENHAGEN.—At the general meeting of Burmeister and Wain's Shipbuilding and Engineering Company, Copenhagen, some interesting facts were disclosed. An extension of the works has been under consideration for several years and the necessary concession in all probability is now forthcoming. Some land has been purchased, but important filling-up work will be necessary. The extension is needed to enable the company to build more and larger motor vessels than hitherto and thus keep the lead to which the yard has attained. The company has concluded contracts for a number of vessels extending over considerable periods and with saving clauses so far as materials go. There are orders for 44 large motor vessels, which will keep the yard busy until 1921, and the value of which is about 100,000,000 kr. (5,550,000*l.*). The company have done much to make themselves independent of foreign supplies by building their own steel works and a large smithy. The repair department has yielded very satisfactory results; the machinery section has been exceedingly busy, and extension of the works in this connection will also be necessary. The sale of stationary Diesel motors shows a slight falling off, but for the current year there are more ordered than the works can supply.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—The Cleveland pig-iron trade shows little change. Very little business is passing, due to the fact that there is next to no pig-iron available for sale. Licences for shipment to neutral countries are unobtainable, and even permits for delivery to France are issued sparingly, so scarce is iron. The shortage is being acutely felt, and the efforts of the Local Committee appointed to regulate distribution are greatly taxed to secure sufficient to satisfy home needs without curtailing supplies to our Allies. All transactions are of a hand-to-mouth kind, and little or no effort is at present being made to do export business. No hope of increased output is entertained as the additional labour necessary for such a purpose is unobtainable. Merchants' idea of the price of No. 3 Cleveland pig for export is 95s. and that may be given as the nominal quotation. A higher figure, however, would no doubt be readily paid if the iron was forthcoming. For home consumption No 3., and the lower qualities, of Cleveland pig, all remained at 82s. 6d. No. 1 was put at 4s. to 5s. above the quotations for No. 3

Hematite Iron.—The conditions in the East Coast hematite branch of the staple industry are very similar to those prevailing in the Cleveland pig-iron trade. There is hardly any free iron, and there is much pressure for delivery. Makers are very heavily committed, and are unable to entertain new business, and, in fact, some doubt is expressed as to whether it will be possible fully to satisfy customers in the near future. Very large deliveries to France are due over the next month or two. For export the quotation is 140s. and upwards for Nos. 1, 2, and 3, and the home price for mixed Nos. remains at 122s. 6d.

Stocks and Shipments of Pig-Iron.—Stocks of pig are very low. Producers have practically none at their yards. The only stock of any consequence is the Cleveland pig in the public warrant stores, and the greater part of that is tightly held by shippers to fulfil current contracts. The quantity held in the warrant stores now stands at 37,316 tons, 35,341 tons of which are No. 3 Cleveland, and 1975 tons other qualities of Cleveland iron deliverable as standard. Since the beginning of the month 2604 tons of No. 3 and 485 tons of standard iron, a total of 3089 tons have been withdrawn from the stores. Shipments of pig-iron from the port of Middlesbrough so far this month average 2185 tons per working day, the total despatches amounting to 19,662 tons. To the same date last month the loadings totalled 15,961 tons or a daily average of 1773 tons, and for the corresponding part of May last year the clearances were returned at 4962 tons, or an average of 551 tons per working day.

Coke.—Coke is in good demand, and is anything but plentiful. Local requirements are heavy. The fixed maximum of 28s. at the ovens still rules for average blast-furnace kinds and up to 30s. 6d. at the ovens is named for qualities low in phosphorus, but an effort is being made to establish a uniform price of 28s. for both qualities, consumers declaring that low-phosphorus kinds are often less suitable for making Cleveland pig-iron than the other and cheaper sorts.

Foreign Ore.—The action of the Government continue to bring down the Bilbao freight, but Mediterranean freights are well maintained. In the open market steamers Bilbao–Middlesbrough can now be fixed at 19s., and as the f.o.b. price at port of delivery for Rubio of 50 per cent. quality is 17s. 6d., the ex-ship Tees price becomes 36s. 6d., but consumers manufacturing iron for home use are still able to arrange, through the Government, freights Bilbao–Middlesbrough at 17s. 6d., so that to them the ex-ship Tees price of best Rubio is 35s. Imports of foreign ore to the Tees so far this month amount to 67,654 tons.

Manufactured Iron and Steel.—Manufacturers of finished iron and steel are busier than ever on Government work, for which there is much pressure for delivery. Little attention is paid to the numerous ordinary commercial enquiries in the market, and export quotations are all but unobtainable. Prices all round are very strong. The following are among the principal market quotations: common iron bars, 13*l.* 15s.; best bars, 14*l.* 2s. 6d.; best best bars, 14*l.* 10s.; packing iron (parallel), 10*l.*; packing iron (tapered), 11*l.* 15s.; iron ship-plates, 11*l.* 10s.; iron ship-angles, 13*l.* 15s.; iron ship-rivets (¾-in. diameter), 16*l.* 10s.; iron ship-rivets (⅞-in. diameter), 17*l.* 10s.; steel bars (no test), 14*l.* 10s.; steel ship-plates, 11*l.* 10s.; steel ship angles, 11*l.* 2s. 6d.; steel ship-rivets (¾-in. diameter), 17*l.* 10s.; steel ship rivets (⅞-in. diameter), 18*l.* 10s.; steel joists, 11*l.* 2s. 6d.; and heavy steel rails, 10*l.* 17s. 6d.

OUR RAILS ABROAD.—The exports of rails from the United Kingdom are falling off more and more. In April they only amounted to 10,510 tons as compared with 21,612 tons in April, 1915, and 30,682 tons in April, 1914; while the aggregate outward movement in the four months ending April 30 was 20,932 tons, as compared with 78,462 tons and 164,277 tons.

"THE RUNNING OF BOILER PLANTS AND NATIONAL ECONOMY": ERRATA.—In the article on this subject published in our issue of April 28, the following corrections are required: On page 395, middle column, line 4 from bottom, for "45" read "61"; in the third column of the same page, line 13 from bottom, for "lb." read "gallons"; and on page 396, first column, in the line of the table relating to "Temperature of Steam," fourth column, for "829.1" read "329.1."

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Glasgow Pig-Iron Market.—Last Wednesday showed the condition of the pig-iron warrant market still unchanged, buyers again offering 82s. 6d. per ton without effect. On Thursday forenoon this figure was advanced to 90s. per ton, but no transactions took place, there being no sellers in the market, while in the afternoon business continued at a standstill. Buyers again quoted 90s. on Friday, but the market remained in the lifeless condition which has ruled for some little time now. No improvement took place on Monday, neither buyers nor sellers being quoted, and a similar state of matters ruled yesterday, Tuesday. Stocks are in consequence very greatly reduced, only 1000 tons of Scotch pig-iron being in store in Glasgow at the present time.

Scotch Steel Trade.—While shell bars for Government contracts continue to be one of the most pressing branches of the local steel trade, it is interesting to note that, both for the Admiralty and for the ordinary mercantile business of the home market, there is a steadily increasing demand for ship-plates. This, probably, has been brought about by the fact that, as mentioned here last week, the construction of a number of merchant vessels in the Clyde yards is to be looked upon as "war work." The demands made for steel by our Allies, notably France, Italy and Japan, is causing some little anxiety, especially when taken in conjunction with the restriction order, but there is every probability the Government may make arrangements for setting aside a certain proportion of finished material in order to comply with these requirements. Although much more steel is now available for the home market, even yet the supply is insufficient to meet the necessities of the Government, which are insatiable. The greatest activity prevails in every direction, and light sections and sheets are in constant demand, the French Government being a heavy consumer, while our own Government has first claim on all the heavier material; indeed the supply can in no way keep pace with the demand. Prices for export keep firm, although there is a decided falling-off of export orders. For prompt home delivery angles are quoted at from 13*l.* 15s. to 14*l.* per ton; ship-plates, 13*l.* 10s. or even 13*l.* 15s.; and boiler-plates, 14*l.* 5s., or more often 14*l.* 10s. or thereabouts, all less 2½ per cent. discount.

Malleable-Iron Trade.—Considering the scarcity of labour, and notably of good puddlers, the output in the malleable-iron trade continues on a very extensive scale. Makers are fully booked up with orders, and there is no lessening of the demands made on their resources. All over prices remain firm, if anything on the upward grade. "Crown" bars of first quality are not changing hands at less than 14*l.* per ton net, and even in not a few cases a considerably higher figure is quoted.

Scotch Pig-Iron Trade.—The demand for pig-iron, particularly for hematite, which is being much used in the steel works doing Government contracts, shows no falling off, and in the local engineering shops there is an equally pressing demand for all grades of foundry iron for castings and other general purposes. Notwithstanding this, there is no over-stocking anywhere—an immediate market is found for everything produced. In consequence of the restriction of export, a very keen oversight is being kept by Government in order to safeguard all available supplies for home consumption. The difficulty of obtaining licences for the export of pig-iron is not tending to an increase of business; indeed, fears are being expressed that it may come to a sudden cessation ere very long. Prices keep firm, and were practically unchanged during the past week, the current quotations for makers' (No. 1) iron being:—Clyde, Calder, Summerlee, and Langloan, 130s. per ton; Gartsherrie, 131s. 6d. (all shipped at Glasgow); Eglinton, 126s. 6d.; Glengarnock, 130s. (both at Ardrossan); Dalmellington, 126s. 6d. (at Ayr); Shotts and Carron, 130s. (both at Leith).

GERMAN MACHINERY IN CHINA.—A very glaring example of the unreliability of German machinery, says the *London and China Telegraph*, is disclosed in the annual report of the Engineer-in-Chief of the Electricity Department of the Shanghai Municipal Council. It appears that there was a serious breakdown of the German-built turbo-alternators at the Riverside Station. It is stated that evidence collected in the United States and England goes to show that the use of the particular metals employed in the construction of the turbine blading was likely to end in disaster, while chemical analysis of the metal conclusively proves that a wrong selection was made in its choice. Further, it seems that two of the machines which developed blade trouble had been in commission only one year and nine months. Other mechanical defects have also since shown up. While it is recognised that the best of machines may give some trouble at times, the electrical engineer observes that trouble such as was experienced with the German-built machines at Riverside is directly traceable to faulty construction and selection of metals. Moreover, figures are quoted in the report showing the yearly cost in repairs and maintenance of British-built machines at Fearon-road Station in comparison with the German machines at Riverside. From these it appears that the expenditure in connection with the German machines is considerably more than double that required for the upkeep of the British; so that the German machines are not only not as good as the British makes, but also they cost twice as much to repair and maintain. This is, indeed, an object lesson which, it may be hoped, will be taken to heart by prospective buyers and users of electrical plant throughout the world.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, *Wednesday.*

Hull Coal Traffic.—From the somewhat restricted details available of the traffic dealt with at the port, it appears that neutral customers are very keenly inquiring for South Yorkshire coal, but the operation of the export licensing restrictions keep the figures down to an average quantity. In the latest returns, it is shown that in the month of April 88,504 tons were exported from Hull, or 20,650 tons per week. A year ago the weekly average export for the month of April was 50,000 tons. Fifty per cent. of the latest export trade went to French and Italian customers in almost equal proportions. The total tonnage for all purposes was 230,325 tons, being 30,000 tons less than the figures for March, and 50 per cent. of the total dealt with in April of last year. Up to date the aggregate trade shows a deficit on the same period of 1915 of half a million tons, and now stands at approximately one million tons.

South Yorkshire Coal Trade.—Chief interest centres in the question of supply. The local demand for steam coal, cobbles, and nuts is on a very large scale. Hard coal pits were never so severely pressed for deliveries as they are to-day and the result is that they are unable to lay by any large reserves, a usual precaution in the event of unduly heavy calls. Pits generally are working extremely well and the full output is not much beyond the quantity required to meet contract liabilities. Shipments of all brands of manufacturing fuel are slightly heavier than last week, but are almost entirely restricted to Allied countries. Fancy prices are being offered, in some instances up to 8s. per ton higher than the home market quotations. Gas companies are only requiring nominal stocks and this section of the trade is easily dealt with. On the other hand the large works and railways are not finding it a light matter to secure the reserves which it is customary to obtain at this period of the year for the busy winter season. House coal inquiries are growing perceptibly less each week, but large orders still remain on the books, for agents and collieries have been in arrears since the turn of the year. Quotations:—Best branch hand-picked, 20s. 6d. to 21s. 6d.; Barnsley best silkstone, 18s. 6d. to 19s. 6d.; Derbyshire best brights, 17s. 6d. to 18s. 6d.; Derbyshire house, 16s. to 17s.; best large nuts, 15s. 6d. to 16s. 6d.; small nuts, 15s. to 16s.; Yorkshire hards, 16s. 6d. to 17s. 6d.; Derbyshire hards, 16s. to 17s.; best slacks, 12s. to 13s.; seconds, 11s. to 12s.; smalls, 8s. to 9s.

Iron and Steel.—The greatly increased call for all classes of steel-making irons, and especially for the superior qualities for the most important classes of war work, is the main feature of the raw material market. Nearly the whole of the furnace output of steel is being requisitioned for munition purposes, and other users are only able to obtain extremely limited supplies under contracts. The open market contains little or nothing. The run on hematites is as heavy as at any time in the history of the war and buyers are thankful to secure adequate supplies at top figures. West Coast are priced at 136s. to 140s., with delivery, and East Coast 128s. 3d., delivered, though in certain cases higher prices have been offered for prompt supplies. Common irons do not show much change, except for the recent revival in the demand for foundry qualities, which has made both Lincolnshire and Derbyshire makers busier. Forge, however, is still the more keenly sought for. All Sheffield works are very actively employed. Production is chiefly confined to munitions, and the ordinary commercial business has been relegated to a subsidiary position. It has been found that the frequent refusal of orders has led to a diversion of much "domestic" trade elsewhere, but this is only regarded as a temporary setback. Manufacturers of machinery and tools for engineering works have innumerable orders. The electro-plate trade is enjoying a period of unwonted prosperity, despite a relative scarcity of materials and labour. Australia and Canada have recently placed large indents for both plate and cutlery, whilst South African buyers have made partially successful efforts to secure the lower-priced table and spring cutlery. It is stated the stocks over there are now almost entirely depleted owing to the reduction in the imports of the last 12 months. An effort is being made to conserve the present staffs of cutlery firms against any further calls of the Army, for the trade is already working on a minimum of labour. The Cutlers' Company have succeeded in securing an important modification of the Government proclamation of April 14, which considerably extended the prohibition of the export of steel. The Cutlers' Company will be allowed to continue the issuing of export certificates for steel which is free from alloys—tungsten, molybdenum, vanadium, nickel, cobalt and chrome—and this will greatly facilitate the transaction of export business. But for this concession great difficulties would have arisen. The Cutlers' Company reserves the right to conduct an expert examination of the goods, to verify the declaration that they are free from alloys. In the overseas general trade the new orders are for steel, tools, saws, machine knives, files and sickles.

NEW ELECTRIC IRON WORKS IN NORWAY.—Some new electric iron works are about to be started in Norway for the exploitation of a new process, which dispenses with the use of coke. Very little is so far known as to the special features of the process.

THE LAURA HUTTE.—Although the Polish works for last year have yielded no profits, the year has resulted in a considerably larger net profit than the preceding year, the figures, interest, &c., having been deducted, being respectively 5,516,082 marks and 3,493,012 marks.

NOTES FROM THE SOUTH-WEST.

Cardiff.—Supplies of steam coal have continued extremely short. In many cases colliery owners have been unable, in consequence, to consider the offers made to them, and only odd parcels are available. Meanwhile there has been no relaxation in the demand from any quarter, and to secure the odd parcels some buyers have been prepared to pay premiums of several shillings per ton. As much as 55s. per ton has been obtained for secondary large steams and 32s. 6d. per ton for smalls. The best Admiralty large steam coal has been, to some extent, nominal; secondary qualities have been quoted at 53s. to 54s. per ton; Monmouthshire black veins at 53s. to 54s. per ton; Western Valleys, at 52s. to 53s. per ton; Eastern Valleys, at 49s. to 51s. per ton; best bunker smalls, at 32s. to 32s. 6d. per ton; and cargo smalls at 22s. to 26s. per ton. In bituminous coal best households have made 23s. to 24s. at the pits; No. 3 Rhondda large, 52s. to 54s. per ton; smalls, 33s. to 34s. per ton; No. 2 Rhondda large, 44s. to 45s. per ton; and No. 2 smalls, 25s. to 26s. per ton. The latest quotation for patent fuel has been 50s. to 52s. 6d. per ton. Special foundry coke for export has made 60s. to 65s.; good foundry coke, 55s. to 60s.; and furnace coke, 45s. to 50s. per ton. As regards iron ore, the current quotations for Rubio have been 35s. to 37s. per ton.

Welsh Trade Matters.—Mr. T. R. Thompson, who had been chairman of the Barry Graving Dock and Engineering Company, Limited, for many years, has retired from the directorate. Under the terms of an agreement by which the Cardiff Channel Dry Docks and Pontoon Company, Limited, has acquired the control of the undertaking, the directors of the Barry Company receive compensation for the loss of their offices. Mr. J. Cory has succeeded Mr. Thompson as Chairman of the new amalgamated concern.—Eleven out of thirteen steamers owned by P. and A. Campbell, Limited, channel passenger-boat owners, are in Government service, leaving only two for the customary work of the company. The profits for the past financial year are returned at 32,980*l.* The directors place 25,000*l.* to the sinking fund account, pay the usual dividend of 10 per cent., and carry forward 5804*l.* Two steamers requisitioned by the Government, the Brighton Queen and the Lady Ismay, have been lost, but the directors hope to re-open the Cardiff and Weston service at Whitsuntide with the steamers Waverley and Glen Rosa.—Lord Rhondda, speaking at Cardiff on what the British Empire owes to commerce, said everybody was asking what was going to happen after the war, and the man who prophesied was the man who knew the least. He did not know what was going to happen, but there would be a period of transition. Capital was going to be pretty dear, and taxation was going to be pretty heavy for a long period. There would be new factors, and the old factors were not going to carry the same weight as before. Under all the circumstances he did not believe any man could express an opinion worth much, and he was not going to prophesy.—At the fourteenth annual meeting of the South Wales Electrical Power Distribution Company, Limited, the Chairman (Mr. W. Gascoyne Dalziel) said that under a working agreement with the Treforest Electrical Consumers Company, Limited, the working expenses were borne by that company, so that there was no revenue account to be issued by the Electrical Power Company. The chairman added that after paying all working expenses and setting aside 5079*l.* for depreciation, there was a surplus of 6757*l.*, and this enabled a half-year's interest to be paid on the old debenture stock, leaving 1756*l.* to be carried to suspense account No. 1, which was in credit to the extent of 3999*l.* Negotiations were at present proceeding with new consumers, which would probably result in a substantial further addition to the demand for power.—Mr. B. Taylor, water engineer, has reported to the Portheawl Council that a contract for laying a new main from Craig-yr-Aber to Smoky Cot has been completed. The cost has been nearly 7000*l.*—Dock companies at Cardiff, Barry, Penarth, Newport, Port Talbot and Swansea, have issued notices that as from June 1 the special concession in rates on vessels calling for bunker coal only will be withdrawn, and that full tonnage rates will be charged. These rates will also be levied on vessels loading coal and discharging part cargoes, if such vessels also take in fuel.—The steamer Santa Crosse, built at Newcastle in 1899, and carrying 1700 tons dead-weight, has been sold to Morgan and Cadogan, Limited, Cardiff. The vessel, which has been re-named the Londswood, was formerly owned in Italy.—The output of coal in South Wales last year showed a decrease of 3,427,128 tons.—Messrs. Edwards, Hepburn, and Company, Managers of the Stella Shipping Company, have paid a second interim dividend of 1s. per fully-paid share for 1915–16, being at the rate of 20 per cent. per annum. The distribution is made free of income tax.—The accounts of Lockett's Merthyr Collieries (1894) Limited, show a profit for the year ended February, 1916, of 45,635*l.*, and a dividend of 10 per cent. is proposed on the ordinary shares, 26,814*l.* being carried forward.—The undertaking of the Cardiff Junction Dry Dock and Engineering Company, Limited, has now been finally transferred to the firm trading as C. H. Bailey. The firm has extensive ship-repairing works at Newport.—Holders of fully-paid 5*l.* shares in the Cardiff Junction have received 9*l.* 11s. 8d. per share, and holders of shares of 4*l.* per share paid have been paid off at 8*l.* 11s. 8d. per share. The undertaking is to be continued as hitherto, with the exception that Mr. Jordan, the general manager, now retires on a pension.—What is known in Bristol as the Royal Line of Steamers has become associated more closely with the Cunard interest. At present there are only two steamers in the Royal Line, a third ship (the Royal Edward) having been torpedoed.

LABOUR EXCHANGES AND TECHNICAL STAFF APPOINTMENTS.

TO THE EDITOR OF ENGINEERING.

SIR,—We shall be pleased if you can arrange to give us a little space in which to sound the opinion of engineers of this country as to the advisability of inserting or answering any advertisements the replies to which are to be addressed to the nearest Labour Exchange. Assuming the Exchanges were instituted to obtain the maximum results from the available skilled labour, are we therefore to be dictated to by men in charge of them, who are absolutely unfit to judge whether or not a man is suitable for the advertised position? Take, for instance, an advertisement inserted for works manager, assistant engineer, or chief draughtsman. Would not the employer be best able to judge which man is most suitable, and is it not to his advantage to receive a number of applications to select from? Again, should an applicant be employed by a Government-controlled firm not wholly on war service, is it fair to that man, the prospective employer, or the country, that his application should be turned down by these so-called managers of Labour Exchanges?

We can quote and verify numerous instances where men who have answered advertisements have merely received, almost by return, letters from Labour Exchanges stating that their application has been unsuccessful, and there has not been time for the application to have been forwarded to and a reply received from advertiser. It is left absolutely to the managers of these bureaux to discriminate whether a man is indispensable or not, and the result obtained is far from benefiting the country in her hour of need, as was intended by the Government.

We shall be pleased to see what others have to say on this subject, which is one of national importance.

Yours faithfully,

TWO INTERESTED ENGINEERS.

"THEORY AND PRACTICE IN THE FILTRATION OF WATER."

TO THE EDITOR OF ENGINEERING.

SIR,—The wide publicity given to the paper read by Mr. Clemence before the Institution of Mechanical Engineers makes it regrettable that so little opportunity was afforded for a full and vigorous discussion of this paper; and it is desirable that a reply should be made, and a protest entered against some aspects of the subject, upon which the author's views cannot be permitted to go unchallenged.

Early in the paper, Mr. Clemence would divide us into two classes: on the one hand, those who support the theory that "the bacterial purification of water by filtration is chiefly due to the mechanical action of straining," and, on the other hand, those who consider "the formation of a film on the surface of a filter a hindrance rather than an aid to purification." There seems little justification for the author's presumption that those who do not support the former theory must necessarily endorse the latter, and become disciples of Armand Puech and advocates of multiple filtration. For the last half century the action of slow sand filters has been the subject of earnest study by many of our leading biologists, who are agreed that the surface film is the principal seat of bacterial activity. Further, every water-works engineer is aware that the formation of a film on the surface of a filter is essential for securing satisfactory results. The author, on the other hand, asserts that "a film, natural or artificial, on the surface of the filtering medium is unnecessary and undesirable." Apparently he has for so long focussed his attention on that limited aspect of the question which is embodied in his own pet theory that one fears he has lost the power of taking that wider survey of the whole subject which is necessary to arrive at an unbiassed conclusion.

Without claiming to be an authority on the bacteriological action of a slow sand filter, I see no reason for disputing the conclusions arrived at by our leading biologists—that the filtering film is both necessary and desirable. It appears only reasonable that purification takes place at the point where the impurities are held up to contact with the purifying agencies, whether bacteriological, chemical or physical. In slow sand filter-beds fed with turbid water, their retention is secured on the surface of the sand, while in those fed with comparatively pure water they penetrate the bed for some distance before being arrested. In the first case, the bacteria are held on the comparatively thin, close-grained surface layer; in the second, by the looser and deeper surface strata. In both cases a filter layer has been formed, varying in density and construction. Many slow sand filter-beds are fed with comparatively pure natural water supplies, and the same penetrative action takes place that the author would have us believe was the exclusive result of multiple filtration. Every water-works engineer will confirm that the lower and more uniform the turbidity of the water supplied to slow sand beds the better and more economical their working; but few consider it desirable to push preliminary filtration as far as the author would have us take it. It is agreed that (to quote the author) "bacterial action is relied on to effect nitrification by natural means, and it appears to be established that the bacteria themselves perish as a result of the disappearance of organic matters to support them." And, again, "nitrifying bacteria continue to multiply until the organic matter is reduced by their agency, when the organisms themselves will disappear." This suggests the danger that an over-elaborate system of multiple filtration, which might secure total elimination of organic matters in solution and suspension before the water comes to the slow sand filter, would result in the starvation of the nitro-bacteria in the final filter, so that they would be non-existent when changed conditions made their presence essential for purification.

Mr. Clemence tells us that "chemicals are not employed in multiple filtration as coagulants to arrest the passage of bacteria," but it is doubtful whether the results he tabulates could be obtained at Magdeburg unless the water had a coagulant present. Fortunately, the author explains that the water is turbid and polluted with refuse from factories, the quantity of organic matter being largely increased in the winter time by refuse from beet-sugar factories. Such a raw water is in a very similar condition to a coagulated supply, and the impurities present have the same characteristic adhesive properties.

The author claims as an advantage of multiple filtration that no chemicals are used, but does not make it clear that in the case of Derwent Valley, where the supply is "an upland water, charged with peaty acids," no appreciable colour removal is effected without a coagulant; and that the towns supplied with water from these works have independently to consider the installation of plant to remove the colour by the aid of chemicals.

The water of the Ganges at Cawnpore is of a totally different nature from that at Magdeburg; there is no natural coagulant, but at certain seasons of the year it contains enormous quantities of silt in an extremely fine state of division, many individual particles being much smaller than bacteria, and devoid of their adhesive properties. The author gives no data of the final results obtained here, either physical or bacteriological, except in one line of his tables, where it is shown that the water discharged by the slow sand filters contains a larger amount of matter in suspension than when it entered, the increase being 2.3 parts per 100,000 on September 4, and 2 parts per 100,000 on September 13, 1912. He would account for this by the escape of the fine filtering medium from the slow sand filters; but this is a very debatable point. In any case, what useful purpose does a "last line of defence" serve that allows the enemy to get through, and augments his ranks with deserters? Having seen the installation at Cawnpore, and noted the penetrative action of the fine silt through the degrossisseurs and prefilters, I am of opinion that it is simply what must be expected. The fine silt of the Ganges penetrates the finest filtering medium, and coagulation is necessary to effect its removal.

Mr. Clemence is persistent in his endeavours to palliate the by no means remarkable results obtained at Cawnpore by laboured explanation of the adverse influence of certain purely adventitious occurrences; but we shall surely be justified in the assumption that the only final results quoted in his paper are amongst the most favourable to support his theories.

The author asserts that settling-tanks serve little purpose, but his Cawnpore tables show that they actually secure 68 per cent. reduction in the suspended matter, whilst the first, second and third degrossisseurs only secure 1.39 per cent., 2.08 per cent., and 4.17 per cent. reduction respectively. He claims that these insignificant percentages of purification are really important, because of the exceedingly fine nature of the suspended matter; but the same argument makes the increase in suspended matter passing through the slow sand filters all the more significant.

The author's argument that the great disadvantage attending the use of settling-tanks in any form is that their periodical cleaning is frequently neglected, is somewhat illogical and is typical of the rather distorted views he takes of the claims of every system of purification other than multiple filtration. Sedimentation is deprecated because the attention involved in cleaning out is so slight that it might be overlooked altogether; multiple filtration, one infers, is advocated because the various stages demand so much attention that it is impossible to overlook it. *Properly designed* sedimentation tanks effect preliminary purification better and cheaper than any other method. They should be constructed at least in duplicate, and furnished with efficient sludging arrangements. Their size must be determined by the nature of the water, but can be reckoned in hours, capacity rather than days.

In a paragraph towards the end of the paper, Mr. Clemence writes: "It is rare to find high-speed filtration relied upon as a single line of defence against water-borne diseases, and in India and elsewhere the results have not been satisfactory where rapid filters alone have been used for the treatment of polluted waters." The suggestion inevitably conveyed by this paragraph, that rapid filtration has proved a failure in India, is not rendered less misleading by the insertion of the word "alone." No responsible person would seriously consider the installation of rapid filtration *alone*; coagulation and sedimentation are essential, and invariably implied by the term "high-speed filtration." The only installation cited, that at Naini Tal, was erected by a foreign firm, who presumably did not give full consideration to the special conditions; but later experience has shown that this must not be accepted as a criterion of the results obtainable by rapid filters in India. After the installation at Cawnpore the Indian Government spent three lakhs of rupees (20,000*l.*) on a searching investigation into the most suitable method of purifying the highly polluted waters of India, and that country was the battlefield of filtration systems during the period from 1911 to 1915. The most successful proved to be, not slow sand beds—even when assisted by multiple filtration—but rapid filtration with coagulation, sedimentation, and sterilisation.

The strongest advocate of mechanical filtration, reading Major Clemesha's report, would agree that it was absolutely fair and unprejudiced, and would be amazed to find that, viewed through Mr. Clemence's distorted outlook, it is really a condemnation of mechanical filtration. His criticism that "where the amount of silt is very great" the percentage of wash-water is high, can be entirely overcome by the provision of suitable sedimentation tanks, with which every well-designed plant is fitted. If Mr. Clemence will not accept Major Clemesha's clear statement of facts, perhaps he will accept the evidence of his actions, when he is advised that as Acting Sanitary Commissioner for All India, he (one of our greatest authorities on all matters relating to the purification of highly polluted tropical waters) has decided in favour of mechanical filtration, and important installations of this type are now under construction in India. The Bombay Sanitary Authorities are now installing at Poonah (the summer capital) a Paterson rapid filtration plant of 4,000,000 gallons daily capacity. The nature of the problem here will be appreciated when it is stated that the raw water at times contains about 1,000,000 fæcal bacteria per c.c., so that even 99.9 per cent. bacterial purification might still leave 1000 dangerous bacteria per c.c. in the filtered water. Similar plant is being installed for the Government of India at Jammu (capital of Kashmir State), and elsewhere.

To attempt a complete reply to Mr. Clemence's remarks upon rapid filtration would involve the controversion of almost every statement which he makes on this subject. It is, unfortunately, only too obvious that Mr. Clemence's pages have been written under the spell of powerful prejudices, which have operated to blind the author to any aspect of the question which does not consort with his own theories. Perhaps the most conclusive reply to his drastic criticisms on the value of mechanical filtration is provided by the decisions of those authorities who have in the last few years investigated the merits of this type of filter, in comparison with slow sand beds and multiple filtration. In one well-known instance the operation of existing slow sand beds fitted with pre-filters has been disappointing, because of the fine clay which penetrates the final filter-beds. The consulting engineers last month recommended the installation of rapid filters for the projected extensions, involving an outlay of over 100,000*l.*, and suggests that the existing slow sand filters should be fed with coagulated water. At Clydebank and at Irvine the slow sand beds have been abandoned, and rapid filters installed, in each case of 6,000,000 gallons daily capacity.

It is to be hoped that when next the author has the honour and privilege of expressing his views from the platform of one of our premier engineering institutions he will take a wider survey of the subject and a more tolerant view of the claims of other systems.

I am, Sir, yours truly,

WILLIAM PATERSON.

India House, Kingsway, May 1, 1916.

"ON THE WHIRLING SPEEDS OF LOADED SHAFTS."

TO THE EDITOR OF ENGINEERING.

SIR,—As I was the first to suggest and actually to use the first of the three methods of calculating the whirling speed used by Mr. Kerr, perhaps I may be allowed to state that I have recently experimentally verified its accuracy for a shaft of variable section, having an actual whirling speed of 893 r.p.m. The bearings were specially made for the purpose, having a ring contact surface of $\frac{1}{4}$ in. width, so that the actual length of the shaft was known. The calculated speed by the above method was 889 r.p.m. The extreme nearness of the two results is probably due to the fact that the elastic constant for the shaft was determined by actually loading the shaft and noting the resulting deflection. In my letter to ENGINEERING, March 5, 1909, where I first suggested this method of determining the critical speed, I stated that I had proved its accuracy for a shaft 12 ft. long and 2 in. in diameter, loaded with ordinary pulleys, and having a critical speed of 240 r.p.m.

Yours truly,

W. M. WALLACE.

37, St. Paul's Road, Manningham, Bradford.

THE DEVELOPMENT OF THE MILITARY AEROPLANE.

TO THE EDITOR OF ENGINEERING.

SIR,—I am sorry Mr. Weiss does not find my reply to his letter "satisfying." I do not propose to prolong the discussion. I have said all I have to say.

Yours faithfully,

F. W. LANCHESTER.

53, Hagley-road, Birmingham, May 8, 1916.

THE NEW RHONE–MARSEILLES CANAL.—This canal, of which we gave an illustrated description on page 316 *ante*, was officially opened on Sunday last, the 7th inst., by the French Minister of Public Works, who was attended by the Under-Secretary for War. The Ministers and the guests travelled through the Rhone Canal tunnel in a train hauled by a compressed-air locomotive.

TRADE AFTER THE WAR.—Mr. E. R. Stettinius, head of the export department of Messrs. J. P. Morgan and Co., returned to New York in the middle of April, after an absence of two months in Europe, and is reported by the *Iron Age* to have stated that most of the reconstruction of the European countries now at war will be done by themselves when the war is ended. Many of the large factories which have sprung up for the production of war munitions will be utilised for other purposes when the war is over; many of the men returning from the front will have to be given employment, and he did not anticipate any great influx of business to the United States in what he termed the work of reconstruction.

THE THEORY OF THE CORROSION OF STEEL.*

By LESLIE AITCHISON, M.Met., B.Sc. (Lond.), Sheffield.

THE problem of the corrosion of iron has been the subject of a great deal of attention during the past 20 years or so. By means of a very large number of experiments, conducted by various workers, amongst whom may be mentioned Sir William Tilden, Messrs. Walker, Whitney, Moody, and Dr. Friend, a number of facts have been accumulated, and two theories have been put forward to account for the actual corrosion of iron. In practically all these cases the material employed has been pure, or nearly pure iron (*e.g.*, the iron foil of Kahlbaum), and in most cases the interest has centred round the attack upon this by pure water (that is, frequently distilled water). At the present time the question is an open one as to the actual details of the corrosion under these conditions, and the present author does not propose to enter upon that particular field. Most of the workers have left the theory of the corrosion of steel, which is a material of much greater complexity of structure than iron, rather well alone. This particular problem may be attacked, however, quite apart from the one stated above, and although it may be rather premature to define a concise theory of the corrosion of steels, yet the author feels that certain points might be discussed with advantage, as some fair amount of experimental evidence has accumulated. Acting upon this, the author wishes to put forward, with all modesty, the points which follow, in the hope that, even if they are not acceptable to all those who have thought out this problem, they may give rise to the expression of some other opinions upon this most interesting subject.

The complex structure of steels, composed as they are almost invariably of carbides embedded in a matrix of some carbon-free material, renders it almost certain that the action going on in a steel during its corrosion is a galvanic one. This conclusion is not seriously at variance with either of the two theories mentioned above as to the essential nature of corrosion. The large number of galvanic couples present in an ordinary sample of steel can be well imagined, and these couples will consist of the carbide on the one hand, and the ferrite or solid solution on the other. This postulates at once that one of the two constituents will be anodic in its action, and the other cathodic. The anodic one will be attacked by the solution —that is, the material composing the anode will pass from the atomic to the ionic condition. The other material, acting as the cathode, will remain in the atomic (or molecular) condition, and hence will appear to be unattacked. The intensity of the galvanic action between the two constituents will depend, other things being equal, upon the potential difference between the two constituents with respect to the corrosive liquid which is in contact with the steel. The carbides in all steels, although of varying chemical composition, will be likely to be possessed of very similar electrical properties, and hence it appears reasonable to assume that the electrolytic solution pressure of all the carbides will be the same, or nearly so. On the other hand, the solid solution, which may range from practically pure iron to an alloy containing many per cents. of a second element, will be a material of very varying electrical properties. As a result the electrolytic solution pressure of this constituent will change very considerably from steel to steel, and will in consequence produce a considerable variation in the potential difference existing between the constituents of the steel. As a result the corrosion should vary a great deal with changes of composition.

All investigators have agreed up to the present in regarding the carbides as being electro-negative—that is, as having positive electro-affinity, or a greater tendency to exist in the molecular than the ionic form. Hence their action should be cathodic, and they should not be attacked by the corrosive liquids. That this is so may be seen by microscopic examination. Two typical structures after corrosion are shown in micrographs Figs. 5 and 6, page 462, the massive carbide being quite obvious in the two cases. The first is a pure carbon steel with 1.25 per cent. of carbon, and the second is a steel containing 0.73 per cent. of carbon and 21.5 per cent. of tungsten.

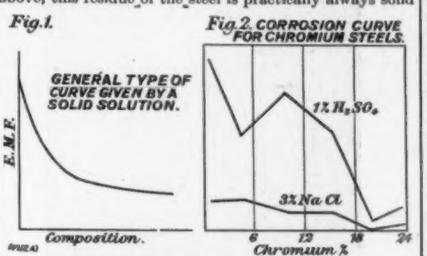
A similar result is obtained by an investigation of the attack of dilute acid upon various steels. By an analysis of the material which goes into solution, and a comparison of this with the compositions of the carbides separated by other methods, it will be found that the carbides are not attacked, and are left in their original form.†

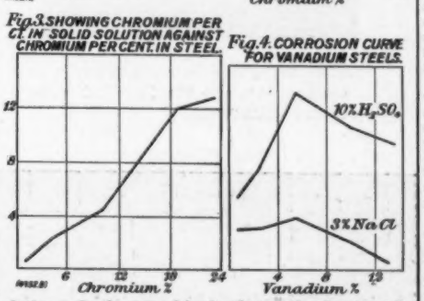
As a result of this the carbides in steel may be regarded as acting in two different directions. First of all, they act as resisters of corrosion. Since they are not attacked by the corrosive liquids, there should be a smaller loss in a steel which is composed largely of carbide than in one which contains only a moderate amount of that constituent. This may be, and probably would be, true were it not for the other action of the carbides. This is connected with their cathodic action. The intensity of the galvanic action will be to some extent proportional to the area of contact between the two constituents. The more finely divided the carbides, the greater will be the area of the surface of contact; and also the larger the quantity of carbide, the greater the available number of surfaces of action. That this is true may be seen from the following figures. The first pair of results demonstrate the second action, of increasing the carbide, whilst the remaining ones show the first action—that is, of increasing the fineness or the state of division of the carbide. This latter is the normal result of the addition of small proportions of a third element—that is, one besides iron and carbon—to steel :—

TABLE I.

Carbon per Cent.	Other Element per Cent.	Loss of Weight in		
		3 per Cent. Sodium Chloride Solution.	Tap-Water.	10 per Cent. Sulphuric Acid.
0.50	—	0.992	0.88	4.57
0.89	—	1.196	0.92	10.82
0.74	W 2.36	1.54	0.97	8.42
0.73	Co 2.68	1.55	0.94	5.12
0.63	V 0.71	1.73	0.90	8.05

These three pieces of evidence—the microscopic, the analytical by sulphuric acid, and the effect upon the corrosion—may be taken as conclusive in proving that the carbides act throughout as cathodes. The rest of the material then becomes the anode in the various galvanic couples present in the material. As stated above, this residue of the steel is practically always solid





solution. In the case of ferrite the solution is extremely dilute, sufficiently so for the ferrite to be termed pure iron, whilst in other cases there may be as much as 12 or 15 per cent. of a second element.

Considering the ferrite alone, two cases arise. First of all there is the common one, in which the ferrite is present in contact with some carbide and acts as the anode in a galvanic couple. This case is perfectly simple, the action coming about in consequence of the solution pressure of the iron (the electro-affinity of iron—*i.e.*, the potential of the metal against a normal ionic solution of its own ions—is — 0.063 volt, iron being one of the metals which have a greater tendency to exist in the ionic than in the atomic condition). The negative electro-affinity in the case of the iron, and the positive (assumed) in the case of the carbide, produce all the essentials for galvanic action. The other case is that of a relatively pure metal—*e.g.*, bar iron—in which practically the whole of the material is composed of crystals of ferrite. As is well known, this material does corrode, and fairly rapidly too. The corrosion on the part of the ferrite in this case has been explained by the galvanic theory, on the assumption that the various grains of the metal have somewhat different solution pressures in consequence of the variation in the orientation of the different crystals. Also the presence of different degrees of mechanical strain in the various crystals is invoked as an explanation of this difference in the solution pressure. It appears possible, however, that neither of these explanations is necessary, in view of the more accurate knowledge that we possess of the structure of pure metals. Many workers have demonstrated the existence of a material in between the crystals of a metal, which has properties quite different from those of the adjacent crystals. The theories that have been advanced as to the nature of this material need not concern the present discussion, since they all have a point of agreement in that they admit the material to be amorphous.*

The orientation of the adjacent grains being different, there exists in this intergranular volume a material having the orientation of neither. It has been shown by various workers that the properties of an amorphous metal are very different from those of the same metal in the crystalline condition. Amongst other things, it has been made very probably true, that an amorphous substance is possessed of a very different solution pressure from that of the crystalline substance. It has been definitely established frequently that a worked material has a much greater solution pressure than an unworked one ;* and as the amorphous layer in between the crystals has a relatively close similarity to a worked material, it is not unreasonable to imagine that the solution pressure of this layer is greater than that of the adjacent crystals. Lüdtke† has shown that mirror silver (which is in the strained or worked condition) will show a potential difference of as much as 0.1 volt when coupled with ordinary silver in dilute acids, and Andrews‡ has found that the strained and unstrained portions of a wrought-iron shaft gave a difference of potential of 0.016 volt, in a solution of sodium chloride. Whichever phase has the greater solution pressure, the result of the existence of a potential difference will be galvanic action, and hence corrosion. This galvanic action would be between the intercrystalline material on the one hand, and the crystals of ferrite on the other. Either of these may be the positive member of the couple, and lose weight. In a perfectly annealed specimen, in which there is but little mechanical strain, it is probable that the action will be confined to that between the ferrite and the cement. If there is any potential difference, however, between the crystal grains due to any cause, then this will add to the effect, and the total corrosion will be the sum of the two actions. It is just possible, though improbable, that the solution pressure of the cement may lie midway between that of the more positive and the more negative grains of ferrite, in which instance the action of the cement will be anodic in one case, and cathodic in another. Taking the simplest case, namely, the one in which the ferrite is roughly at the same potential throughout, and the intergranular cement at another, then there should be an action developed at the junction of the two substances. The action may not be confined to this face of contact, but will proceed at a maximum rate on that plane. The result should be that the lines of junction of the crystals show this more intense action, and the evidence should take the form of a relatively deep pit sunk round the crystals. That this evidence is to hand may be seen from photograph Fig. 7, page 462, which shows a melted bar iron, having the following composition : carbon, 0.07 per cent. ; silicon, 0.018 per cent. ; manganese, 0.09 per cent. ; sulphur, 0.031 per cent. ; phosphorus, 0.010 per cent. after undergoing corrosion in sodium chloride. This theory would account more or less completely for the corrosion of a pure metal.

Passing on to the question of solid solutions, several very interesting points arise at once. Assuming that the action in the case of steel containing carbide and solid solution is similar to that in those consisting of carbide and ferrite—that is, galvanic with the carbide as cathode—it should be evident that the controlling factor in this instance will be the solution pressure of the solid solution, and this will vary with the composition of the solid solution.

The solid solutions found in steels have very various compositions, and these have been determined indirectly by Arnold and Read,§ and directly by the author.‖ The results obtained are of interest, and show that in the case of molybdenum, vanadium, and tungsten, these elements do not enter into the solid solution until a relatively high percentage of the element is present. At first the tungsten, vanadium, and molybdenum are associated entirely with the carbon, and form a part of the carbide. In the case of vanadium, the "saturation" percentage of the carbide is about 5.4, for tungsten about 11.7, and for molybdenum about 19.0. Below these percentages these elements are not found in the solid solution. As a result the concentration of the solid solution for these elements, even after they do find their way into this constituent, is never very high. In the case of chromium, this element appears in both carbide and solid solution from the start, and hence the solid solution is much more concentrated in chromium at lower percentages than for any of the previous elements. Nickel behaves in a way just the opposite of vanadium and molybdenum. In the case of that element, the carbide is found to be free from nickel until the steel contains more than 8 per cent. of nickel. Prior to this, the solid solution receives all the nickel, and in consequence is more concentrated at lower percentages than that found in any of the other alloys. Up to the present our knowledge of the actual electromotive-force curves of these alloys of iron with vanadium tungsten, molybdenum, &c., is not very great, but the general type of curve provided by a solid solution is well known. In general it is a logarithmic curve of the form indicated in Fig. 1. It will be granted that in all the alloys designed to resist corrosion it will be necessary for the solution pressure (as reflected in the electromotive force) of the solid solution to undergo some considerable change from that of iron, in order that the difference of potential between the solid solution and the carbides shall be sufficiently small as to minimise corrosive action. From the electromotive-force curve it should be evident that there is no sudden change of solution pressure in the alloys forming the solid solution, and that in consequence it will be necessary for the solid solution to become relatively concentrated in the alloying element before the required change of solution pressure can be accomplished. The corollary to this is surely that there is only likely to be any diminution of corrosion if the new element

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* Paper read before the Iron and Steel Institute, Thursday, May 4, 1916.

† *Cf.* author, Trans. of the Chemical Society, 1916, vol. cix., page 288; and Arnold and Read, Journal of the Iron and Steel Institute, 1910, No. 1, page 169 (ENGINEERING, May 13, 1910); 1911, No. I., page 240; 1912, No. I, page 215 (ENGINEERING, June 7, 1912); Journal of the Institution of Mechanical Engineers, 1914, No. I., page 233 (ENGINEERING, March 27 and April 3, 1914); 1915, No. I., page 247 (ENGINEERING, March 26, 1915).

* *Cf.* Rosenhain and Ewen, Journal of the Institute of Metals, 1912, No. 2, page 149; 1913, No. 2, page 119 (ENGINEERING, September 12, 1913); and Humfrey, Iron and Steel Institute : Carnegie Scholarship Memoirs, 1913, vol. v., page 86.

* C. E. Fawsitt, Journal of the Society of Chemical Industry, 1906, vol. xxv., page 113.

† Annals of Physical Chemistry (2), 50, page 678.

‡ Proceedings of the Institution of Civil Engineers, 1894, vol. cxviii., page 10.

§ *Loc. cit.*

‖ Trans. of the Chemical Society, 1915, vol. cvii., page 1531, and 1916, page 288.

finds its way into the solid solution early in the series, and also becomes present in reasonable proportions. For any element that goes into solid solution in the steel, a small percentage is not likely to be of the slightest value in resisting corrosion. That this view is true may be seen from the following cases.

The author has examined the influence of composition upon the corrosion of steels by determining the loss of weight experienced in various liquids by steels containing carbon only, and carbon with varying percentages of tungsten, vanadium, chromium, cobalt, molybdenum, copper, nickel, and manganese.* The results of these experiments show that very few steels containing a third element have any advantage to offer over those containing merely iron and carbon. The most conspicuous exceptions are the steels containing a high percentage of chromium. The corrosion curve for these alloys is shown in Fig. 2, and it will be seen that it is only in those alloys where there is a good deal of chromium that any improvement occurs. As was stated above, in these steels in the solid solution is found to be quite high, this is not surprising if the theory of the influence of electromotive force be allowed.

Another case is that of the vanadium steels. The curves for the corrosion of these steels are shown in Fig. 4 and it will be seen that there is an increase in the corrosion up to the steel containing 5.84 per cent. of vanadium. After that the corrodibility decreases very appreciably. This is what might be expected in view of the composition of the solid solution. No vanadium is to be found in the solid solution up to the saturation point of the carbide, which is about 5.4 per cent. of vanadium in the steel. At 5.84 per cent. the solid solution is found to contain 1 per cent. of vanadium, at 10.3 per cent. it has 3.8 per cent., and at 13.45 per cent. as much as 7.2 per cent. Hence some distinct influence upon the electromotive force might be expected in consequence of the change of composition. If this change of solution pressure has resulted, then there will be a fall of corrosion, such as is actually found to happen.

chromium steels that resist corrosion so successfully. The structure of a non-corrosive chromium steel is shown in micrograph Fig. 8, below, and it may be seen at once that this steel is quite the reverse of homogeneous, being composed of a very intimate mixture of solid solution and carbide. Here the number of possible galvanic couples per square centimetre of exposed surface is enormous, and everything that could be an aid to corrosion is apparently present. Yet there is no corrosion in weakly attacking media. This can only be due to a lack of power to go into solution on the part of the solid solution—that is, to a negligibly small solution pressure with respect to these media. Again, take the case of a material of conspicuous chemical homogeneity—the bar iron illustrated in photograph Fig. 7, below. Here there is corrosion to an appreciable extent, and this can only be due to a difference of solution pressure amongst the constituents of the material, as stated above. A further example may be quoted, that of a solid solution in which twinning of the crystals is present. The microstructure revealed by corrosion in this case is illustrated in micrograph Fig. 9, and this steel corroded to a very considerable extent. In this case there could

FIG. 5. 1.25 CARBON STEEL AFTER CORROSION.

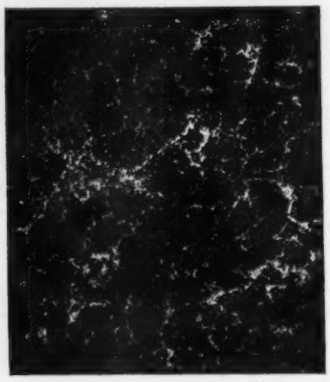

FIG. 6. STEEL CONTAINING 0.73 PER CENT. CARBON AND 21.5 PER CENT. TUNGSTEN AFTER CORROSION.

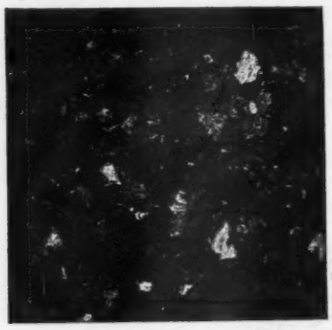

FIG. 7. PHOTOGRAPH OF MELTED BAR IRON CONTAINING 0.07 PER CENT. C, 0.018 Si, 0.09 Mn, 0.031 S, 0.010 P. CORRODED IN SODIUM CHLORIDE.

FIG. 8. STRUCTURE OF NON-CORROSIVE CHROMIUM STEEL SHOWING INTIMATE MIXTURE OF SOLID SOLUTION AND CARBIDE.

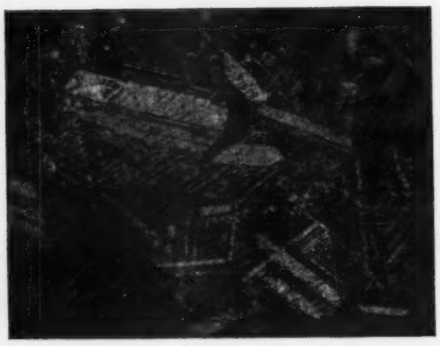

FIG. 9. TWIN-CRYSTAL MICROSTRUCTURE AS REVEALED BY CORROSION.

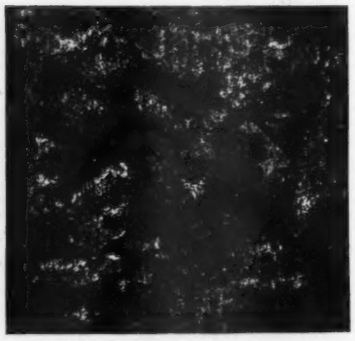

FIG. 10. 0.89 PER CENT. CARBON STEEL AFTER CORROSION.

the chromium is found in both the carbide and the solid solution, from the smallest percentages and the composition of the solid solutions for the steels whose corrosion was shown in Fig. 2 are given in Fig. 3. There it will be seen that the solid solution does contain a reasonably high percentage of chromium in those alloys which resist corrosive attacks. Nickel steels are another series of materials which have a definite resistant action towards corrosive media, and in this case the conditions are very similar to those holding in the case of chromium. In these steels the nickel does not enter the carbide to any extent until more than 8 per cent. is present, and hence there is produced a solid solution which contains a reasonably large percentage of this element. Thus in the two best-known examples of anti-corrosive steel the conditions demanded by theoretical consideration are fulfilled. Yet another example may be put forward. In the steels containing cobalt there is found to be a fall of corrosion with an increase in the percentage of the cobalt. This is remarkable in one sense, because in the steels containing the higher percentages of cobalt the carbides had decomposed and precipitated graphite, a material calculated to cause a violent increase of corrosion if the solid solution has a suitable solution pressure. This increase of corrosion, however, does not take place, and this can only be due to the reluctance of the solid solution to act in an anodic manner. As the percentage of cobalt

In the other steels examined—*e.g.*, those containing molybdenum and tungsten—there is no resistance to corrosion to be found. The compositions of the solid solutions in these cases show that there is never a formation of anything approaching a concentrated solution. In the molybdenum steels, the one containing 20.7 per cent. of molybdenum has a solid solution in which the percentage of molybdenum is about 2.2. In the tungsten steels there is no tungsten to be found in the solid solution up to about 12 per cent., and beyond that only a small proportion, since the tungsten associates itself with the carbide part as both a double carbide of iron and tungsten, and also as a tungstide of iron.* As a result one would not expect that these steels—*i.e.*, containing molybdenum or tungsten—would have any great resistance to corrosion, and this is found to be the case. These experiments all appear to support the theory that the corrosion of a steel is determined mainly by the solution pressure of the solid solution which the steel contains.

The microstructures of these ferro-alloys are also a powerful support of this same theory. This idea has been held for a long time, that non-homogeneity in a steel is the primary factor in producing corrosion. This may be correct within certain limits, and given a satisfactory definition of homogeneity, but it is generally assumed in consequence of this idea, that a steel possessed of a complex structure is bound to be corrosive. This view can no longer be held in face of the structure of the

be no lack of chemical homogeneity, the only difference between the various parts of the crystals being one of orientation, which would be reflected by a variation of the solution pressure. Yet the mere fact of twinning does not necessarily produce a corrosive solid solution, for some of the nickel steels containing a considerable percentage of nickel have twinned crystals in abundance, but yet only corrode very slightly. Surely these facts support the theory that the solution pressure of the solid solution is the important factor in deciding the corrosion or non-corrosion of a steel.

Following upon the action first of carbides and then of solid solutions (including ferrite) comes the behaviour of pearlite—the remaining constituent of steels. This component in the structure of steels is, of course, a mixture in definite proportions of ferrite (or solid solution) and a carbide (simple or complex). Two actions are possible with respect to this constituent: it may act either as a mixture or as a whole. Both these opinions have been held. Viewing the matter from the point of view of the solution pressure of the constituents, it is a little difficult to see how the pearlite can act as a separate simple constituent. The potential of a eutectic, or a mixture, is that of the constituent having the greater solution pressure—that is, the one showing the greater tendency to become ionic—and in the case of pearlite this undoubtedly is the ferrite. If, then, the pearlite be acting as a whole, it should corrode in accordance with the potential difference set up between itself and the npighbouring component, which is the large areas of the ferrite. But if the pearlite be regarded as a whole, then

* *Cf.* author, Trans. of the Faraday Society, 1915, vol. xi., No. I. and No. II., 1916, and Trans. of the Chemical Society, 1915, vol. cvii., page 1531.

* Arnold and Read, Journal of the Inst. Mech. Eng., 1914, page 223 (ENGINEERING, March 27 & April 3, 1914).

the solution pressure of the pearlite and of the ferrite will be the same, or almost the same. Hence there should be no corrosion. Also, if there were corrosion, then there should be a preferential attack upon either the ferrite or upon the pearlite. Taking the other view, that the pearlite acts not as a whole, but as a mixture of ferrite and carbide, then the corrosion proceeds in accordance with the usual potential difference set up between these two constituents. This will mean that in any particular grain containing, *e.g.*, ferrite and pearlite, the two components of the galvanic couple will be the carbide on the one hand, and the ferrite forming the body of the grain on the other. Hence, as the whole of the ferrite in the grain is part of the same electrical unit, whether it belongs to the pearlite or to the ferrite, the anodic action should take place all over the ferritic surface exposed to the corrosive liquid. In this way the ferrite will dissolve all over the surface of the grain, and the carbide will be unattacked.

If a series of pearlitic steels of different carbon content be corroded, and then examined microscopically, it will be found that the resulting structures are almost indistinguishable one from the other. In no case, after an attack of about 10 days, can the pearlite structure be observed, and, except for the attacks at the crystal boundaries present in a bar iron and absent in the steels, the pearlitic steels all present the appearance of a corroded iron. The carbide has disappeared, unless a fairly large piece is present when it is left standing in a field composed apparently of badly pitted and corroded ferrite. There is no trace of a separate area of attack of ferrite in pearlite, and it is not possible to distinguish between a steel containing 0.4 per cent. of carbon and one with 0.9 per cent. A typical structure is that shown in micrograph Fig. 10, a steel with 0.89 per cent. of carbon, after corrosion. This can only mean that the ferrite is attacked throughout, whether in the free ferrite areas or in those of pearlite. The carbides will not have been attacked, this having been proved by many experiments quoted above, and hence their disappearance from the steel can only be due to mechanical means. This, of course, is quite a probable explanation of the action which has taken place, the ferrite being attacked by the corrosive liquid and dissolved away. This removes the support which held the carbide in position, and allows it to fall out during the washing which must necessarily precede microscopic examination after corrosion. The presence of the loose carbide on the surface of a corroded sample that has not been disturbed is usually fairly obvious. If the carbide is massive, it is likely to be rooted more deeply in the mass, and hence on light corrosion is not removed. This accounts for the structure of the steel shown in Fig. 5, in which the carbide of the crystal boundaries (the cementite) remains clear and unattacked, whilst that of the pearlite, which normally occupies the body of the crystal, has disappeared. In some of the alloy steels which contained pearlite, and were examined, the corrosive action had not gone far enough to remove all the carbide of the pearlite from its matrix, and traces of the pearlitic structure might be still seen in the resulting micro-section.

The conclusions to be drawn from the above may be summarised as follows :—

(1) That the corrosion of a steel takes place purely by the action of the ferrite or the solid solution.

(2) That the action upon pure ferrite may be due entirely to the potential difference set up in consequence of the different solution pressures of the grains of the metal and the inter-granular cement, it being probable that this latter is possessed of a greater electromotive force.

(3) That the percentage of the third element added to iron and carbon in steels must be sufficiently great to produce a fairly high percentage in the solid solution, if there is to be any beneficial effect from the use of this element.

(4) That the electromotive force of the solid solution with respect to the corrosive liquid is the deciding factor in the corrosion of a steel.

(5) That the pearlite in a steel does not corrode as a whole, but as a mixture of ferrite and cementite, the disappearance of the latter being due to mechanical, and not to chemical action.

(6) That carbides are not decomposed by ordinary corrosive agents, and that they act merely as cathodes to the anode of the ferrite or solid solution.

THEORY AND PRACTICE IN THE FILTRATION OF WATER.*

By WALTER CLEMENCE, Member, of Shortlands, Kent.

(*Concluded from page* 426.)

RAPID FILTRATION.

RAPID or mechanical filters have been adopted in many places during the past 10 years, generally for the treatment of waters which are organically and bacteriologically pure, but which require special treatment by chemicals for the removal of peaty acids or colour. In some instances, as at York and Cheltenham, they are used as scrubbers or roughing filters for the clarification of the water prior to filtration in open sand-beds. In both cases the speed adopted for the latter is unusually slow, at York 21 gallons per sq. ft. per 24 hours (F. O. Oertel, Report to Government of the United Provinces, India, page 26), and at Cheltenham 31½ gallons per sq. ft. per 24 hours (Proceedings of the Institution of Water Engineers, vol. xvii., page 74).

Mechanical filters have also been adopted by the Weardale and Consett Water Company as roughing filters and for treatment of a plumbo-solvent water with lime previous to sand filtration. A description of these roughing filters appeared in *The Engineer*, May 28, 1915. Mr. Robert Askwith, the engineer to the company, has kindly supplied the author with further information with regard to this plant. The sand filters were formerly blocked rapidly with the lime used for neutralising the peaty acids in the water. The roughing filters, which have a capacity of 2,000,000 gallons per 24 hours, cost 3228*l.* complete. In the article referred to, it is stated that when this class of plant is used by itself for filtering, it is rated at only half this capacity, so that the cost would then be 3228*l.* per million gallons. The quantity of lime used averages 95 lb. per million gallons, and the cost of lime is 1*l.* 4s. 3d. per ton. The roughing filters are cleaned once in two days. The final filters are worked at an average speed of 43 gallons per sq. ft. per 24 hours.

A rapid filtration plant of enclosed or pressure mechanical filters has recently been completed at Oldham, and is described in *The Engineer*, July 30, 1915. The total capacity of the installation is given as 3,360,000 gallons per 24 hours, and the cost complete with auxiliary plant as 20,000*l.*, or 5952*l.* per million gallons. The speed adopted is 122 gallons per sq. ft. per hour. Lime and aluminoferric are the chemicals used.

It is rare to find high-speed filtration relied upon as a single line of defence against water-borne diseases, and in India and elsewhere the results have not been satisfactory where rapid filters alone have been used for the treatment of polluted waters. The system was tried in India, at Naini-Tal, for the treatment of water derived fron a series of springs, the majority of which showed signs of pollution. Tests of the system were ordered by the Government and carried out in 1912 by Captain C. L. Dunn, who described the result of his investigations in a paper read before the All India Sanitary Conference held at Madras, in November, 1912. The tests of the installation were carried out over a period of nearly five months under varying meteorological conditions. Captain Dunn stated "that on increasing the amount of sulphate of alumina the efficiency was greatly increased, but that coliform bacilli could still be recovered from 1 cub. cm. of the water which had passed through the filter." At the same Sanitary Conference Major W. Clemesha, I.M.S., Sanitary Commissioner for the Province of Bengal, presented an interesting report on his investigations in the use of rapid filters in his district. This report deals with mechanical filters of the pressure and gravity type.

Major Clemesha does not consider the pressure filter safe under any circumstances when dealing with a polluted water, though he favours the gravity filter He sums up the advantages and disadvantages of the two types as follows :—

PRESSURE FILTERS.

Advantage.—They are a very useful and compact arrangement for improving the appearance of small quantities of water that is already bacteriologically safe, for they remove many of the bacteria and a great deal of suspended matter and silt.

Disadvantages.—(*a*) In order to get a decent result from a bacteriological point of view, the head on the filter should never fluctuate. This is extremely difficult to bring about mechanically.

(*b*) In some installations where settlement is impossible, the difficulties of adding the correct amount of alum are very considerable, and without the proper use of alum the filters give little purification.

(*c*) Pressure filters cannot be constructed with a greater diameter than 8 ft., hence they are practically useless for large installations on account of the initial cost, which for large installations of, say, 10,000,000 gallons per day, would be absolutely prohibitive.

(*d*) It is practically impossible to run the filter at a constant rate of discharge. This is necessary if high bacteriological purity is desired.

GRAVITY FILTERS.

(*a*) A gelatinous film of aluminium oxide is added to the top layer of the sand in order to remove bacteria. This is brought about by adding alum to a water containing the oxycarbonate of lime.

(*b*) All gravity filters to give good results must work at a constant head and flow per sqare foot of surface until they become choked, when re-washing is necessary.

Advantages.—(1) A mechanical gravity filter is capable of giving a pure water at the rate of 100 gallons per sq. ft. per hour. This is 50 times as fast as an ordinary slow sand filter of the same area which yields about 2 gallons per sq. ft. per hour. It will be perfectly obvious that in certain places a small compact installation may possess many advantages as compared with the amount of space taken for slow sand filters.

(2) With proper working there can be no doubt that a very pure water is obtained with this type of filter.

(3) The initial cost of these filters is considerably less than slow sand filters.

(4) The amount of trouble caused by adverse conditions, such as a very muddy water, is overcome with much less difficulty and less deterioration in the quantity of the water than in slow sand filters.

Disadvantages.—(1) All filters, including slow sand filters, are liable to accidents; therefore the water on arrival should have passed the safety change. By this I do not mean that it should be free from all traces of pollution, but that the true fæcal nature of the bacteria should have been altered by natural forces.

(2) The filters require washing up, and filtered water has to be provided for this.

(3) In places where the amount of silt is very great, the amount of water required for washing may at times reach as much as 20 per cent. of the total output of the plant.

(4) The working charges of these filters are high :—(*a*) The whole of the water to be pumped has usually to be raised to a greater height than is necessary for slow sand filters. (*b*) The cost of alum is a big item. (*c*) The cost of pumping wash-water is also a source of expense.

It would appear, however, that the advantages enumerated above relate to filters dealing with waters which have already been decanted with sulphate of alumina for 12 to 15 hours, and Major Clemesha does not rely on rapid filtration unless the water before arriving at the filter has "already passed the safety change." It is clear that working costs may mount to a figure which, if the annual charge is capitalised, will far outweigh any initial saving in cost of construction over slow sand filters. Also it will be seen from Major Clemesha's statement that, in extreme cases, in order to provide the amount of filtered water necessary for washing, the initial cost must be increased by one-fifth, and the annual working expenses also increased considerably, while at certain seasons only 80 per cent. of the water treated is available for the supply.

In effect, all that is here claimed for rapid filtration is that at a high cost for chemicals and working expenses it will still further purify a water which has already passed the safety change by previous treatment.

With rapid filtration any reduction in organic matters in solution must take place during the decantation of the water before filtration, as the high speed adopted does not allow of nitrification during the passage of the water through the filtering materials, while the nitrifying organisms which might effect a chemical change are absent from the filter bed owing to the frequent disturbance of the sand for cleaning.

Much interesting information as to the comparative cost and efficiency of slow and rapid filters is contained in reports presented by the Edinburgh and District Water Trust in 1910–12. At Edinburgh in 1911, 3,157,000,000 gallons were treated by slow sand filtration and 668,000,000 gallons by rapid filtration with sulphate of alumina. The results were carefully compared and a report issued by Messrs. Ritchie and McGowan. It was unfortunate that, during the period over which the inquiry extended, the raw water treated by rapid filtration was, from the chemical standpoint, relatively pure.

Filtration had practically no effect on the saline constituents in the water or on the free ammonia.

From the bacteriological standpoint, the raw water during the period of observation contained a very considerable number of bacteria developing at blood heat. It was also constantly under suspicion of containing excretal bacteria in relatively small amounts of the water, viz., 1 to 10 cub. cm.

The rapid filtration process did not satisfactorily remove organisms of the excretal type, and did not bring the filtered water up to the standard degree of purity usually required in potable waters, viz., that the water should not contain more than 100 bacteria per cub. cm.

There is evidence that after being washed the filters did not at once attain their maximum capacity for acting on the water, and that at the end of the 24-hour period they were again working unsatisfactorily.

A comparison of 19 observations on samples of effluent from the slow sand filters and of 20 observations on samples from the rapid filters gave the following results :—

	Slow Sand Filters.	Rapid Filters.
Blood heat bacteria per cub. cm.	6	17
Summer heat ,, ,,	8	100

The general conclusions arrived at by Messrs. Ritchie and McGowan included an emphatic expression of opinion that the slow sand filter is much more efficient as a bacterial purifier than the rapid filter.

A second report by the engineers to the Edinburgh and District Water Trust is equally interesting as affording a comparison between the cost of construction and working of slow and rapid filters in the same district, when the cost of labour is relatively the same for both syatems.

From this report it would appear that the results from the rapid filters, referred to in the report of Messrs. Ritchie and McGowan, were obtained from a water treated in settling-tanks previous to filtration. The cost of filtration is stated in the engineer's report as follows :—

The capital cost of the six more recently constructed slow sand filters was 45,870*l.*, and their total annual cost was 2514*l.*, while the total quantity of water filtered by them was 3,157,000,000 gallons. But to get really efficient filtration, the six filters should not pass more than about 2,520,000,000 gallons per annum, and that at 2514*l.* would be equal to 20s. per million gallons.

Regarding the rapid filters, the total capital cost of 12 8 ft. filters, *without taking into account any pipes or drains, or land, for the filter-house and settling-tanks*, amounted to 6660*l.* The annual cost was 867*l.*, and the total quantity of water filtered was 668,000,000 gallons, that being equal to 26s. per million gallons; but the filters were capable of dealing with 2,000,000 gallons per day, equal to 730,000,000 gallons per annum. If the filters had been worked at their maximum capacity the result would have been 730,000,000 gallons filtered for 867*l.*, equal to 23s. 9d. per million gallons. It would therefore appear that the cost of filtering by ordinary sand filtration might vary from 16s. to 20s. per million gallons as compared with 24s. to 26s. per million gallons for rapid filtration.

The information available as to the comparative efficiency of slow and rapid filters when used as a single line of defence against water-borne diseases shows that the advantage is entirely with the slow filter, which without artificial aids will effect bacterial purification with

* Paper read before the Institution of Mechanical Engineers, April 14, 1916.

greater regularity and certainty than the rapid filter, while it does not appear possible that nitrification can take place in the rapid filter, because the nitrifying organisms are removed at the very commencement of the process of straining.

Conclusions.—Rapid or mechanical filtration is therefore an entirely artificial process; the mechanical action of a gelatinous film is relied upon to eliminate bacteria by straining, and organic purification is brought about by using oxide of iron or other substances as a filtering medium or by chemical treatment of the water before or after filtration.

Multiple filtration aims at the complete clarification of the water by pre-filtration before final treatment by the well-known process of slow sand filtration. By preventing the formation of a film on the surface an endeavour is made to establish nitrifying action throughout the whole mass of the sand and to maintain the filter in this condition for the longest possible period. So far as bacterial purification and reduction of organic matter in solution are concerned, these are effected in multiple filtration by natural means. It is therefore important that the final sand filters in this system should be as deep as possible, having regard to convenience in working, as the greater the depth the more time will there be for the nitrifying action to take effect.

As regards the cost of filtration, although it is frequently claimed that the capital cost of mechanical filters is less than that of slow sand filters, it must be remembered that, in England at any rate, mechanical filters have chiefly been adopted in the case of upland waters of comparative purity, while polluted river waters are usually treated by the method of slow sand filtration. It is obvious that the more polluted the water the more elaborate must be the means of purification provided, and it is probable that for any given water there is little to choose between the capital cost of slow or rapid filters if both are provided on a sufficient scale to effect satisfactory purification.

The claim that mechanical filters can be cleaned more rapidly and at less cost than open sand-beds is fallacious. A given number of cubic feet of turbid river water will contain sufficient matter in suspension to block 1 sq. ft. of filter surface, whether of a slow or rapid filter. If, therefore, a mechanical or rapid filter has one-hundredth part the area of a slow sand filter, it will require cleaning 100 times for one scraping of the slow filter supplied with the same water if no coagulants are used; but if a coagulant is used, the mechanical filter will become blocked still more rapidly, as a considerable amount of the available "loss of head" is required to force the water through the artificial film on the filter.

The figures already quoted seem to show that, under equal conditions, the total cost of rapid filtration is greater than that of slow filtration in open beds. In multiple filtration the working costs are reduced to a minimum, as the final filters only require scraping at rare intervals, while with air-cleaning for the gravel beds, and a travelling scraper for cleaning the pre-filters, an installation capable of dealing with several million gallons per day can be controlled by one man, except on the rare occasions when it becomes necessary to scrape a final filter. But it is now recognised that pure water must be supplied at whatever cost, and the most important question is that of safety.

The author has endeavoured to show that there are in theory and practice two methods of filtration, rapid and slow, and as success with high speeds necessitates the use of a coagulant film, the question of the "filtering film" is really the dividing line between the two methods. In dealing with waters liable to contamination, it would appear that greater safety is secured by adopting natural methods of purification by slow-speed filtration than by economising space, increasing the speed, and endeavouring to attain purification by artificial means. If the slow speed of the open sand filter tends to greater security, this should outweigh all other considerations in the design of an installation for treating water for potable supplies.

Aids to Filtration.—In recent years many experiments have been made with various methods of sterilising water in order to satisfy the demand for a water which would show zero as a result of a laboratory bacteriological test. The three methods which have been adopted are: (*a*) Chemical sterilisation; (*b*) ozone; (*c*) ultra-violet light. There can be no doubt that it is possible by the careful application of any of these methods to destroy all bacteria in a polluted water.

In the first method either chloride of lime or chloride of potash is used in sufficient quantity to destroy the bacteria. These chemicals must be employed before filtration, which is necessary to clarify the water and remove the chemical employed for sterilisation. In this case, as all the bacteria, including nitrifying organisms, are destroyed as a preliminary to purification, there can be no reduction of organic matters in solution by nitrification in the subsequent process of clarification, so that the system is hardly applicable to the treatment of river waters liable to organic contamination. Chloride of lime is sometimes added to a water after filtration in very minute doses, but as Dr. Adolf Kemna frankly states, this is simply with a view of still further reducing the number of microbes, and he is "distinctly of opinion that there is no hygienical necessity for this in the case of a carefully filtered water, but it is an extra precaution, and is worth while, in that it gives the low bacterial 'counts' in which some of the local hygienists seem to revel." Dr. Kemna is referring to the practice at the Antwerp Water Works.*

The systems of sterilisation by ozone or ultra-violet rays are applied after filtration. The methods of application of these and also of the chlorine treatment were carefully tested at Marseilles during the summer of 1910.* Later developments of ozone and light treatment on the Continent had for their object the reduction in the area of the filter-beds used for clarification of the water, or an increase in the output from existing beds by increasing the speed while relying on sterilisation for bacteriological purification. It should be stated that in order to obtain complete sterilisation with ozone or ultra-violet light treatment, the water must first be rendered absolutely free from all matters in suspension, and with the latter method colour must also be eliminated. But at present the installation of either system costs more than the most elaborate filtration plant for treating a given quantity of water, while the working costs are many times heavier.

It seems to be established also that if a water containing organic matters in solution is sterilised, a sample from the steriliser may show satisfactory bacteriological results on testing, while the same water after storage will show a very high bacterial content. In ENGINEERING, August 15, 1913, there appeared a table compiled from the weekly returns from the Paris Municipal Laboratory at Montsouris. This shows that at St. Maur the samples taken after sterilisation by ozone gave on three occasions the low figure of 1, 1, and 4 microbes per cub. cm., while samples of the same water taken from the delivery mains gave 144, 420, and 168 microbes per cub. cm. respectively. The explanation seems to be that in waters containing much organic matter in solution, nitrifying bacteria which gain access to the water after sterilisation will continue to multiply until the organic matter is reduced by their agency, when the organisms themselves will disappear.

Rapid filtration can no doubt effect the complete clarification of water with the aid of chemicals and coagulants. Reduction of organic matters may be brought about by chemical treatment, and bacteria can be eliminated by various methods of sterilisation. But slow sand filtration still remains the only method which, without artificial aid, will effect clarification, reduction of organic matters by nitrification, and elimination of pathogenic organisms.

APPENDIX I.

NOTES ON AN EXPERIMENT WITH SULPHATE OF ALUMINA FOR THE REMOVAL OF COLOUR AT THE MULTIPLE-FILTRATION INSTALLATION OF THE DERWENT VALLEY WATER BOARD AT BAMFORD.

For this experiment a complete set of degrossisseurs was used, or one-fourth of the whole, and the quantity of water treated was 3,000,000 gallons per 24 hours, representing the maximum speed for which the installation was designed.

The filtering materials originally in use were entirely removed and replaced by much finer materials, as follows:—

First Strainer.—The coarse crushed limestone, ¾-in. gauge, was replaced by a bed of fine calcspar 12 in. thick, which had passed through a sieve of 17 S.W.G., four meshes to the lineal inch, and was retained on a sieve of 18 S.W.G., five meshes to the lineal inch.

Second Strainer.—The medium crushed limestone, ¾-in. gauge, was replaced by a bed of fine calcspar 12 in. thick, which had passed through a sieve of 18 S.W.G., five meshes to the lineal inch, and was retained on a sieve of 26 S.W.G., 16 meshes to the lineal inch.

Third Strainer.—The finely crushed calcspar, ¼-in. gauge, was replaced by a bed of Leighton Buzzard sand 18 in. thick, screened through a sieve of 18 S.W.G., five meshes to the lineal inch, and retained on a sieve of 28 S.W.G., 24 meshes to the lineal inch.

A solution of sodium carbonate was first added to the water at the inlet to the main distributing channel to neutralise the acidity and make it slightly alkaline. The quantity of sodium carbonate used was about 1 grain per gallon.

The sulphate of alumina was added to the water at the inlet to the first strainer, the quantity used being 1¼ grains per gallon.

It was found that the water after passing the three strainers was free from stain, and the effect of the treatment was to convert the brown and turbid raw water into a clear water of a pale bluish green when examined in a 2-ft. glass tube.

The available loss of head on each of the first two strainers is 12 in. only, and on the pre-filter of sand 2 ft., and these heads were absorbed after 48 hours, and it became necessary to clean the beds after treating 6,000,000 gallons of water. The existing air-cleaning plant, designed for use with coarse gravel, was found sufficient for washing the fine gravel and the sand bed in about 4½ hours. Raw water was used for flushing the beds during cleaning, the quantity used being about 5 per cent. of the water filtered. There was no precipitate (hydrate of alumina) in the treated water for the first 40 hours, when a very small quantity appeared.

The above information has been supplied to the author, who wishes to point out that the installation was designed for use with much coarser filtering materials in the degrossisseurs than those employed during the experiments. Unfortunately, there are no pre-filters at Bamford between the degrossisseurs and the final filters, and the quantity of chemicals used was considerably in excess of what is required when using chemicals for the removal of colour in installations in which a pre-filter is provided.

In such cases sodium carbonate, if required, can be mixed with the water after the turbidity has been reduced in the first strainer, and the sulphate of alumina added at a later stage.

The experiments are interesting as showing that colour can be completely removed by multiple filtration if desired, while the fact that installations of this type are divided into a large number of compartments in successive stages secures a thorough mixing of the chemicals employed and consequent economy in the quantity required, while there is an obvious advantage in being able to add the chemicals at any stage of the multiple process of filtration.

APPENDIX II.

NOTES ON SOME RESULTS OF THE WORKING OF THE MULTIPLE-FILTRATION PLANT AT ACCRA, GOLD COAST COLONY.

Owing to the local conditions it has not yet been possible to work this installation at its full capacity. Chemical analyses have been made since October, 1915, on samples from the various units of the plant working at speeds varying from 100,000 to 250,000 gallons per 24 hours, but with the area of the final filters reduced so as to give a rate of filtration equal to or above the designed speed.

The raw water has been found to be much more impure than had been supposed from the figures quoted by the author of the paper in the brief description of the installation.

Out of 59 samples of raw water taken at various points between the river intake and the inlet to the filters, 31 samples, or over 52 per cent., gave a figure for albuminoid ammonia in excess of 0.05 part per 100,000, the highest figure being 0.074, and the average of the 31 samples referred to giving 0.059 part per 100,000. The organic impurity of the water is therefore considerably greater than had been supposed, while the effect of storing the water in reservoirs has the effect of increasing the amount of albuminoid ammonia.

On three occasions, series of samples have been taken of the water at the inlet to the filters and of the treated water after each stage of filtration. The samples were taken at such intervals of time that the analyses relate to the same water in its passage through the whole installation.

The following tables show the results obtained:—

Sample from	Albuminoid Ammonia in parts per 100,000.	Reduction on Raw Water.	Percentage Reduction on Raw Water.	Reduction on Previous Stage of Treatment.	Percentage Reduction on Previous Stage of Treatment.
1st Trial, December 3-5, 1915.					
Raw water ..	0.061	—	—	—	—
Rougher No. 1..	0.052	0.009	14.05	0.009	14.05
„ No. 2..	0.050	0.011	18.19	0.002	3.84
„ No. 3..	0.045	0.016	26.23	0.005	10.00
„ No. 4..	0.037	0.024	39.34	0.008	17.77
Pre-filters ..	0.029	0.032	52.45	0.008	21.62
Final filters ..	0.019	0.042	68.85	0.010	34.48
				0.042	
2nd Trial, December 3-5, 1915.					
Raw water ..	0.059	—	—	—	—
Rougher No. 1..	0.052	0.007	11.86	0.007	11.86
„ No. 2..	0.048	0.011	18.64	0.004	7.69
„ No. 3..	0.038	0.021	35.59	0.010	20.83
„ No. 4..	0.032	0.027	45.76	0.016	15.78
Pre-filters ..	0.027	0.032	54.23	0.005	15.62
Final filters ..	0.012	0.047	79.66	0.015	59.25
				0.047	
3rd Trial, 9-11 December, 1915.					
Raw water ..	0.057	—	—	—	—
Rougher No. 1..	0.055	0.002	3.52	0.002	3.52
„ No. 2..	0.049	0.008	14.03	0.006	10.90
„ No. 3..	0.047	0.010	17.54	0.002	4.08
„ No. 4..	0.040	0.017	29.82	0.007	14.89
Pre-filters ..	0.024	0.033	57.89	0.016	40.00
Final filters ..	0.015	0.042	73.68	0.009	37.50
				0.042	

The results show a progressive reduction in organic matter through the successive stages of treatment of a very impure water. The second and third trials took place shortly after a serious breakdown of the pumping machinery, which necessitated a complete stoppage of the filters for several days. A considerable improvement on the results already obtained may therefore be looked for when it is possible to work the filters at a regular speed; but the figures show a very remarkable reduction in organic matter, by filtration and aeration of a polluted water, without the aid of chemical treatment.

In the Annual Report of the Resident Engineer to the Gold Coast Government for 1915, it is stated that since the multiple filters have been in use there has been a very large reduction in cases of guinea-worm disease, to which the natives were much subject. The Report adds: "This disease may be said to have disappeared except for imported cases from the bush." This appears to show that this malady is essentially a water-borne disease, contracted through drinking impure water, and that it may be eliminated entirely by efficient filtration.

CURTIS AND ZOELLY TURBINES.—We read in the *Rivista Marittima* that a dispute has arisen between the Fore River Shipbuilding Corporation, builders of the Curtis turbine, and Messrs. Cramp, builders of the Zoelly turbine. The paper in question states that the former contend that in the construction of the Zoelly turbine Messrs. Cramp have applied many items which are protected under the Curtis patents.

* Transactions, Institution of Water Engineers, vol. xvii., page 216.

* ENGINEERING, January 27, and February 3, 1911.